METALSMITH 3 & 2

PREFACE

This book is written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of METALSMITH 3 AND 2. Combined with the necessary practical experience, the information in this training course will prepare the reader for advancement in rating examinations.

The first chapter of this book contains general information concerning the work and responsibilities of the Metalsmith, a brief discussion of the Metalsmith's place in Naval organization, and references to a valuable supply of source material. Following chapters are concerned with tools, equipment, and materials used in the Metalsmith's work; heat-treating; metal testing; soldering; brazing; oxyacetylene and arc welding and cutting; sheet metal measurement, layout, and fabrication; and blacksmith work and forging. Chapter 13 includes damage control, watertight integrity, and fire fighting. The la[illegible] records and reports, and a discussion of the importance of safety in hand and machine processes in the Metalsmith's work.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Navy Training Publications Center of the Bureau of Naval Personnel, and personnel of the Naval establishments specially cognizant of the duties of a Metalsmith.

CREDITS

All illustrations published in Metalsmith 3 and 2 are official U. S. Navy photographs unless designated below.

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STUDY GUIDE

The table below indicates which chapters of this book apply to your rating. To use the table, follow these rules:

1. Select the column which applies to your rating. If you are in the Regular Navy you will use the column headed "ME" which is the general service rating. If you are a member of the Naval Reserve you will use the column headed by your particular emergency service rating — MEG, MES, MEB, or MEW.

2. Observe which chapters have been marked in your *rating* column with the number of the *rate* to which you are seeking advancement.

3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. (See Appendix X of this book for a complete list of qualifications for advancement in rating.) In order to gain a well-rounded view of the duties of the general service rating, it is recommended that you read the other chapters of this book even though they do not pertain directly to your rating.

4. Here is an example: If you are a member of the Naval Reserve studying for advancement in rating to Metalsmith B (Blacksmith) third you will select the column headed MEB. Following this column down you will observe that you must study chapters 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15.

CHAPTER	ME	MEB	MEG	MES	MEW
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4	2	3,2	2	2	2
5	3,2	3,2	3,2	3,2	3,2
6	3,2	3,2	3,2	3,2	3,2
7	3,2	3,2	3,2	3,2	3,2
8	3,2	3,2	3,2	3,2	3,2
9	3,2	3,2	3,2	3,2	3,2
10	3,2	3,2	3,2		3,2
11	3,2		3,2	3,2	3,2
12	3,2		3,2	3,2	3,2
13	3,2	3,2	3,2		
14	3,2	3,2	3,2	3,2	3,2
15	3,2	3,2	3,2	3,2	3,2

READING LIST

NAVY TRAINING COURSES

Blueprint Reading (NavPers 10077).
Use of Tools (NavPers 10623).
Mathematics, Vol. I (NavPers 10069).
Mathematics, Vol. II (NavPers 10070).

OTHER PUBLICATIONS

Appropriate chapters of BuShips Manual.
Specifications for Welding, Appendix 5.

FIRST PUBLISHED IN 1947

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education officer. *A partial list of these courses applicable to your rate follows:

Number	Title
J 362	*Arc Welding.*
J 363	*Gas Welding.*
J 367	*Introduction to Machine Industry.*
EM 912	*Blueprint Reading at Work.*
J 277	*Sheet Metal Drafting.*
J 371	*Metallurgy and Heat Treatment.*

*"Members of the United States Armed Forces Reserve Components when on active duty are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more; or if they have been on active duty for a period of 120 days or more regardless of the time specified in the active duty orders."

CONTENTS

CHAPTER 1

THE METALSMITH'S WORK

GET THE WORD

You've gazed from a porthole at the receding shoreline and seen the familiar landmarks of the world you know slip over the horizon. And you have gazed from that same porthole far at sea. You didn't see much perhaps, but look again. Take a look at the porthole itself. That porthole is one of the smoothest pieces of metalwork you've ever seen. Look at that hull—she's a good ship. She'll take a squall or an engagement in her stride. You know that the world that you signed on to see is not framed by that porthole but is right here aboard. The men you know, and the work you do, make that world. The work is mighty important to you and the crew. For you it has to be interesting and for the crew it has to be good. The captain on the bridge, the cook in the galley, the Quartermaster at the wheel—all have interesting and important jobs. The Metalsmith's job is just

as interesting and important. That's the job you have picked out for yourself.

Here it is! If there is a locker to be made, a ventilation duct to be repaired, a hatch to be opened, or a shot-away bow to be replaced—you are it.

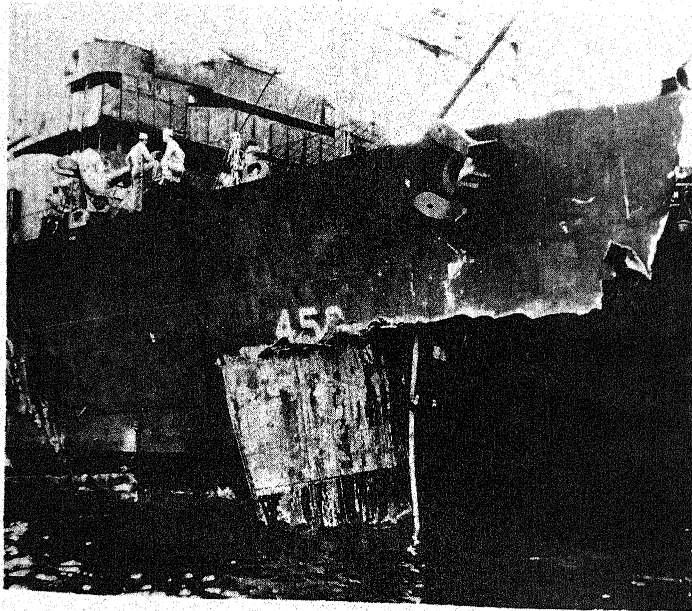


Figure 1.—Damaged bow of the U. S. S. O'Bannon.

Your side arms are mallets, stakes, snips, brakes, and torches; your ammunition is tin, copper, aluminum, iron, and steel. You weld, braze, solder, bend, brake, cut, form, and fabricate. This means that yours is a job of variety and interest, calling for a lot of special skills and know-how.

This book is written to guide you in your study—it cannot make an expert of you. That can be done by you and you alone. You will have to get your hands on the tools and the metals and do the job again and again. Read everything that concerns your work and then try it out. Do a lot of listening, especially to the old "dogs." Get the word!

MAN YOUR STATION

Aboard ship your working station is ordinarily a shop located somewhere in the machinery spaces. The size of the shop and the amount of equipment it contains depend largely on the size of the ship. If you are on a destroyer, you may have only a locker and a tool box, and you'll do your work in any available space. On a light cruiser, you'll have a small shop or share a shop with other crew members of your department. On a large cruiser, aircraft carrier, battleship, transport, repair ship, or tender, you'll have more space in which to work. Plenty of equipment is available.

On the larger ships your work is directed and supervised by First Class and Chief Metalsmiths. On smaller ships you're pretty much on your own.

Many Metalsmiths are stationed at shore establishments, either in the States or at advanced bases; others are assigned to repair ships, to special ship repair units, or to amphibious units which repair landing craft.

RATINGS

Metalsmiths are classified into GENERAL SERVICE RATINGS and EMERGENCY SERVICE RATINGS. If you are on duty in peace time, you will be General Service. General Service is designated (ME), Rating Code 520. If you are in the Reserve (either the Organized Reserve, Fleet Reserve, or Volunteer Reserve), you will come under one of the Emergency Service Ratings. Emergency Ratings are designated MEG-521, MES-522, MEB-523, and MEW-524. In the event of war or the declaration of a national emergency, all hands will be assigned to one of the Emergency Service Ratings. Any new men recruited under those conditions will likewise be assigned one of the Emergency Service Ratings.

General Service Metalsmiths (ME) must have all of the qualifications of men who hold Emergency Service Ratings. Specifically, they must be qualified to lay out, fabricate, and repair metal structures, both light and heavy gage. As an ME-520, General Service Rating, you will make repairs involving weld-

ing, riveting, and calking of decks, structures and hulls. You will work plate and sheet metal. You will do hot and cold forming and heat-treating of metal. You'll belong to a damage control party in which you'll be required to do patching or repairing of leaks in the hull, tanks, or bulkheads. You'll make air tests, and check watertight integrity. In fact, there isn't much in the whole field of metal work that you will miss.

Metalsmiths G (MEG-521) make repairs involving welding, brazing, drilling, riveting, and calking of decks, hulls, bulkheads, and tanks. They make templates, and use shop, hand, and power-driven tools. MEG's check watertight integrity by making air tests of doors, hatches, ports, manholes, and tanks.

Metalsmiths S (MES-522) fabricate and repair sheet metal and light plate structures. They lay out, shear, rivet, weld, braze, tin, and solder sheet metal. They use hand-operated, power driven, and shop tools. Personnel classified MES are assigned to the CB's and to Ship Repair Units.

Metalsmiths B (MEB-523) forge, heat-treat, case-harden, and forge-weld metals. They also fabricate hand tools, metal shapes, structural members, hooks, shackles, and brackets. They operate furnaces and forges. MEB's are assigned to CB and ship repair activities.

Metalsmiths W (MEW-524) are expected to perform all welding operations with high skill, using both gas and electric equipment. MEW's are assigned to CB and ship repair activities.

SHIPBOARD ORGANIZATION

Ships of steel. Gear and equipment made of such metals as iron, copper, steel, tin, aluminum, and brass. That's what you'll find today. Even the mess tables are made of steel—stainless steel. Ships and their equipment must be repaired and maintained. That's where you fit into the work picture. But do you know how you fit into the organization of your ship and the Navy? Take a look at figure 2 and find yourself on the chart.

You are in the Repair (R) Division. Notice that alongside you are Machinery Repairmen, Damage Controlmen, Pipe Fitters, and other skilled ratings. On small ships you will be

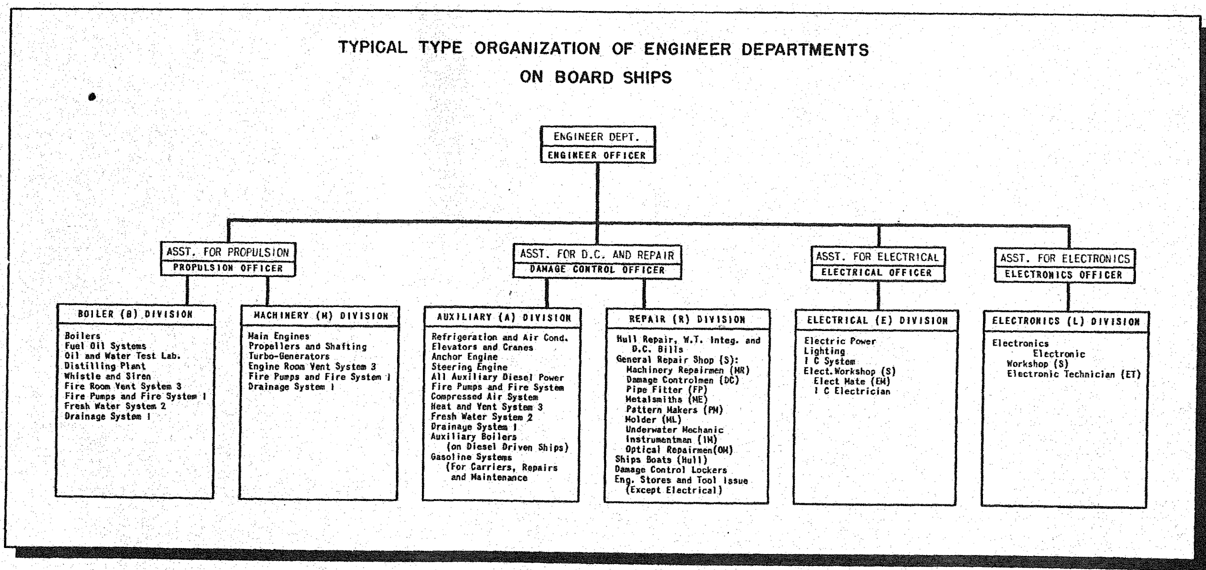


Figure 2. — Typical organization of engineer and hull departments on board ship.

working with these ratings in the same general repair shop. On large ships, or on shore stations, you will be working with other Metalsmiths in a shop of your own.

There are generally two divisions under the damage control officer: Your division and the Auxiliary (A) Division. Sections of Machinists Mates in the (A) Division handle refrigeration and air conditioning, elevators and cranes, and anchor engines. The compressed air system and a part of the fresh water system are also handled by the (A) Division. Part of the heat and ventilation system is maintained by the (A) Division; the rest of it is maintained by the Boiler (B) and the Machinery (M) Divisions.

The (B) and (M) Divisions are under the main propulsion officer who, like your damage control officer, is an assistant to the engineer officer. On ships that have boilers, main and auxiliary engines in one space, the (M) and (B) Divisions may be combined into one Propulsion Division.

The other two divisions on large ships are the Electrical (E) and the Electronics Repair (L) Divisions. Each of these is under an officer who is an assistant to the engineer officer. On small ships they may be combined under one assistant.

The Engineer Department is headed by the engineer officer. His organization is so flexible that he may assign overlapping duties to get a job done. The smaller the ship, the more overlapping the duties will be.

In short, the functions of the Engineer Department are:

1. The operation and maintenance of the ship's machinery.
2. Damage control.
3. Hull and machinery repair.
4. Electronic repair.
5. Power, light, and water repair and maintenance.
6. Cleanliness and upkeep of spaces assigned Engineer Department, including underwater fittings.

The other departments of your ship are the Gunnery (or Deck) Department, the Operations Department, the Supply Department, and the Medical Department.

The Gunnery (or Deck) Department is headed by the gunnery officer on combatant ships and by the first lieutenant

on noncombatant ships. This department handles the operation, maintenance and repair of armament, and the personnel and equipment connected with deck seamanship.

The Operations Department is responsible for navigation and piloting. Combat information, intelligence, and operational evaluation and planning are also the business of the Operations Department. In other words, this is the department that gets information about the enemy and plans the best method of attacking him.

The Medical Department performs a very necessary part of the operation of your ship by treating the sick and wounded, and by providing dental care. The health, sanitation, and hygiene of the ship is in its hands.

The Supply Department procures, issues, and accounts for general stores, small stores, ship's stores, and provisions. This department is also responsible for the preparation and serving of your chow.

If you are aboard a repair ship or tender, you will have a Repair Department headed by a repair officer. This department services other ships, prepares repair schedules and makes repairs whenever necessary.

On aircraft carriers and seaplane tenders there is an Air Department headed by an air officer. This department is responsible for launching, landing, and handling operations of its own aircraft. It also maintains and repairs its aircraft. The handling of aviation fuels and explosives is also the job of this department.

Each department is responsible for the cleanliness and upkeep of its own assigned spaces.

The executive officer is second in command on your ship. The departments work directly under him. He supervises all departments and sees that they all work together to carry out the assigned task or mission.

The commanding officer is responsible for the operation and maintenance of the whole ship's many detailed functions, as well as for the welfare of the crew. He has a lot of responsibility and, therefore, a lot of authority.

As a petty officer, you are the representative of the division

officer. You will be called upon to carry out his orders faithfully and fully. In order to do this job well, you must understand the organization of your ship thoroughly. It may differ in detail from the typical organization but basically it is the same. Get the organization of your own ship well in mind and discover just where it fits into the picture of the organization of the Navy.

YOUR SHIP AND THE NAVY

Your ship, cruising about in the Pacific or the Atlantic, could accomplish little if it were not a part of a well-laid plan. In spite of all the ships the Navy has, little could be accomplished if they were not part of a large organization with a centralized command. During World War II we discovered the necessity of combining all our military efforts under central direction. That is why the Military Establishment was set up. The Navy, the Army, and the Air Force are combined under the Secretary of Defense who is next in command to the President of the United States.

Under the Secretary of Defense are the Secretaries of Navy, Army, and Air Force. Serving directly under the Secretary of Navy is the Chief of Naval Operations (CNO). Military command and policy control stem from the President of the United States and are handed down through the Secretaries and the Joint Chiefs of Staff to CNO. The Chief of Naval Operations is responsible for the Operating Forces which include the Pacific Fleet, the Atlantic Fleet, the Naval Forces Europe, and the Sea Frontiers. He is also in command of the district commandants in charge of the Shore Establishments.

For tactical or administrative command, your ship will operate in one or more of the following classifications:

A Unit—a single vessel.

A Section—normally one-half of a division.

A Division—an organization composed of two or more vessels.

A Squadron—an organization consisting of two or more divisions.

A Flotilla—two or more squadrons of light vessels or submarines with flagships and tenders. Light cruisers are not included in this organization.

A Task Force—an organization for the accomplishment of a particular job or task, consisting of any type or organization of ships necessary to do the required job.

If your ship is a destroyer or smaller, it will probably operate in a division. The organization of the Navy is flexible enough, however, so that in an emergency your ship may operate as a unit or in a section. In any case, if you are a part of the Atlantic Fleet or the Pacific Fleet, your ship will be a part of a Task Force.

Now if you are snowed by all of this information, take a look at the chart shown in figure 3.

To get a better understanding of just how you fit into the picture of the organization, trace the heavy line from the President down to your position. Of course, you are not really on the bottom as shown in the chart; but you already know the steps below you and the tough struggle you had getting where you are now.

The organization described is designed primarily for war. It is set up in such a way that our peacetime organization may be rapidly expanded in case of a national emergency. Out of every war come experiences by which we profit, and this—the reorganization of the national military structure—is a direct result of the experiences gained in World War II.

The Navy needs men who understand and who are interested in Navy organization. If you always know a little more than is required, there will be room up the ladder for you.

UP THE LADDER

You have ambition to get ahead. That's why you're studying this book. The Navy likes ambitious people and provides many opportunities for them to improve themselves. The Navy has standards to maintain, however, and the most logical way to maintain them is to require men to meet certain qualifications for efficiency in a job or rating. These requirements are set

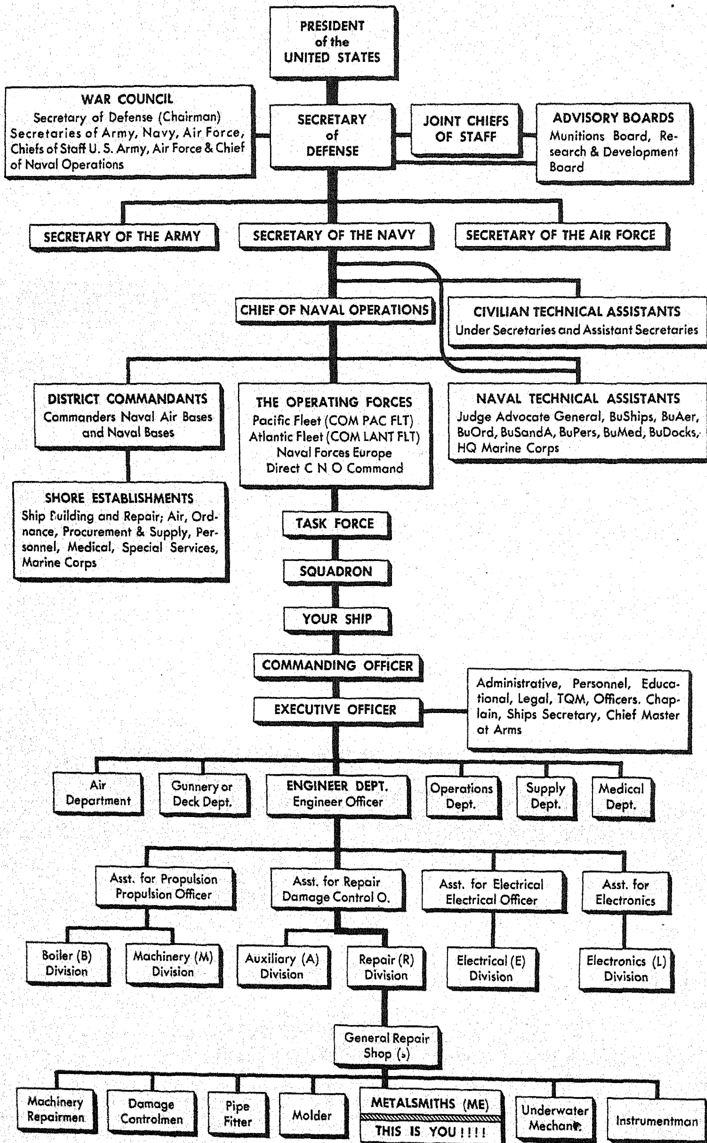


Figure 3.—The Military Establishment and the U. S. Navy.

forth in *Manual of Qualifications for Advancement in Rating*, NavPers 18068.

But regardless of rating, certain abilities are required of all men in the Navy. These are listed in the *Manual of Qualifications for Advancement in Rating* under the heading "Military Requirements for all Men in the Navy." Of all the qualities demanded of a petty officer, leadership is the most important. Books have been written on leadership but they cannot make you a leader. You must train yourself to become one. Self confidence is the basis of good leadership, but it must be supported by knowledge and a genuine enthusiasm for your particular job.

Read Navy books. Think Navy thoughts. Talk Navy language. Yours is a world of ships, boats, and seamanship. The men who operate Navy equipment are your kind of men. Learn to recognize their uniforms and insignia. By looking at a uniform you can tell how long a man has been in the Navy, what kind of work he does, how much pay he gets, and in what campaigns or theaters of war he has been.

Be a good shipmate. Learn thoroughly the things that help others. The lives of your shipmates may depend upon whether you have learned first aid, swimming, life saving, or the use of oxygen breathing apparatus. Get the scoop on organizations that handle personal problems. There is such an organization in your own command. On small ships, your division officer will have the word. On the large ships, you will have a Navy chaplain to whom you can talk. Do you know about the assistance available through Red Cross and Navy Relief? Are you familiar with rules governing family allowances and allotments, and National Service Life Insurance? Knowing about such things will help make you an outstanding petty officer.

Be military! Take pride in your uniform and your ability to handle men. As a petty officer you will be required to handle men in infantry drill, calisthenics, and formations. You will make routine musters and prepare watch lists. A good petty officer is a man who presents himself and his men favorably whether under fire or on parade.

You must not only acquire knowledge and master skills; you

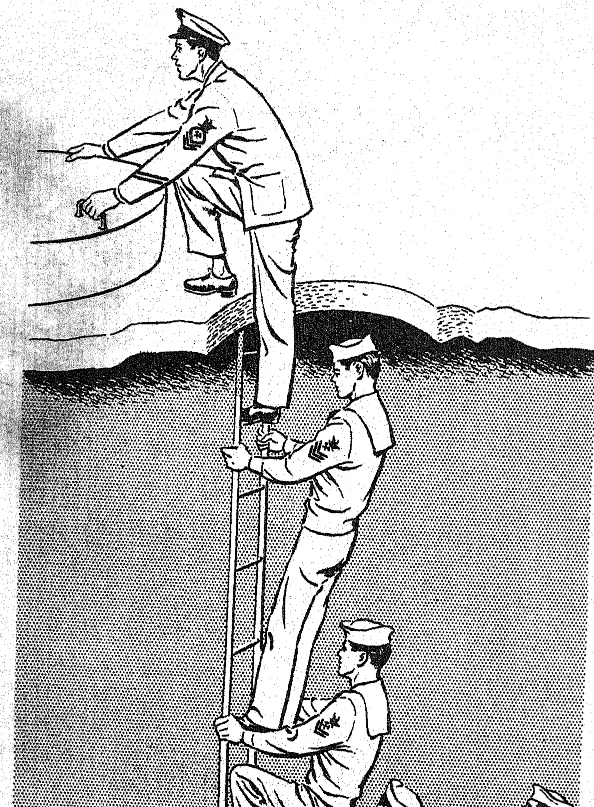


Figure 4.—Up the ladder.

must be able to teach others what you learn. In the Navy, you are either instructing or being instructed all of the time. Take a look at the best first class and chief petty officers you know. They are men who mastered methods of training others.

In the appendix you will find qualifications required for advancement in the Metalsmith rating. Check yourself on these qualifications. If you don't know the answers, break out your library and start digging. You'll find the answers in this book and in others listed later in this chapter. Your educational officer has these books—ask him for those you want. Be sure that you understand the qualifications required of you. Master them so that when a billet opens you will be on your way UP THE LADDER.

NORMAL PATH OF ADVANCEMENT

Whether or not you have followed the normal path of advancement to where you now are, you will be expected to have a thorough knowledge of the duties and requirements for the Seaman Recruit (SR), Fireman Apprentice (FA), and Fireman (FN). If you are a little rusty on some of the details, check out a copy of NavPers 10213 *Fireman* and do a bit of "bright work." You should also review the *Bluejacket's Manual.*

There's no limit to how far you can advance. It depends upon your own enthusiasm, ability, and hard work. Of course, the billets have to open up, too; but if you have what it takes, you'll get a billet when it does open. Rate by rate you can advance to Chief Metalsmith. If you are officer caliber, the next step is Warrant Carpenter E3 (Ship Repair Technician). Carpenters E3 broaden their knowledge and training to include functions of the pipe fitter and damage controlman ratings and knowledge of ship salvage and diving operations. They act as assistant engineer or repair officers, assistant damage control officers, and assistant construction officers (CB).

STUDY REFERENCES

Basic NavPers manuals will give you a good foundation of information which you will need as you go up the ladder. For

good reading that will give you the story of the origin and development of the U. S. Navy from the days of "fifty lashes with a cat-o'-nine-tails" to "Operation Crossroads," you can't beat *Your Navy*, NavPers 10600.

In addition to the prescribed training courses for each of the ratings there are a number of Basic Training Courses which you will find helpful. In the field of tools, one of the best is *Use Of Tools*, NavPers 10623. This manual covers basic tools from hammers and screw drivers to precision instruments. It also includes use, maintenance, and precautions to be observed. You will find this Basic Navy Training Course an interesting, well illustrated publication, handy and convenient for ready reference. Likewise, *Hand Tools*, NavPers 10306, a Navy Training Course prepared especially for aviation, is good reading and informative. You would also do well to spend some time reading *Basic Machines*, NavPers 10624, especially if you are the curious type who likes to know what makes things tick. In the study of *Basic Machines*, you will become familiar with the underlying principles behind all tools and machines. Besides being chuck-full of information, this book contains a lot of meat for bull sessions. Also, if the letters DC mean nothing more than District of Columbia to you, it might be a good idea for you to do a bit of boning on *Basic Electricity* NavPers 10622.

Metalsmiths use a lot of mathematics, especially in layout and pattern making. You don't have to be an Einstein to be a good Metalsmith, but you may need to hold field day on your math section. Check out a *Mathematics*, NavPers 10620 and you'll find everything from simple addition to logarithms. The section on practical geometry, areas, and volumes will be most helpful to you in metalwork.

For the best information on reading blueprints or doing layout work, *Use of Blueprints*, NavPers 10621, and *Blueprint Reading and Layout Work*, NavPers 10305, are the good references. Of course, these books are only a few of the many references available for your use. But with them you can find the answers you are going to need to pass your examination for advancement.

You are no doubt familiar with *General Training Course For Non-Rated Men*, NavPers 10601. Now there's a book that's full of word. For information regarding the duties of petty officers, *General Training Course For Petty Officers*, will give you the information necessary. It includes sections on leadership, military duties, instructing, and survival at sea.

For technical instruction, including standards and quality of work required, refer to the *Bureau of Ships Manual*.

Study the BASIC COURSES thoroughly and follow up with the additional information in the general references. With all that information and what you can get from this book you are ready to use your eyes and ears when you visit a metalsmith shop and see Metalsmiths at work. You can be a petty officer by meeting the minimum requirements. If you want to be an outstanding PO, you're going to have to know more than is required.

QUIZ

Select the one best answer to each of the following statements.

1. If you are rated (ME)-520 with previous experience or special training in welding and a National Emergency is declared, you probably would be assigned the rating of —
   (*a*) (MEG)-521.
   (*b*) (MES)-522.
   (*c*) (MEB)-523.
   (*d*) (MEW)-524.

2. Metalsmiths (ME) are ordinarily assigned to the Engineer Department under the—
   (*a*) Repair (R) division of Damage Control and Repair.
   (*b*) Auxiliary (A) division of Damage Control and Repair.
   (*c*) Machinery (M) division of Propulsion.
   (*d*) Boiler (B) division of Propulsion.

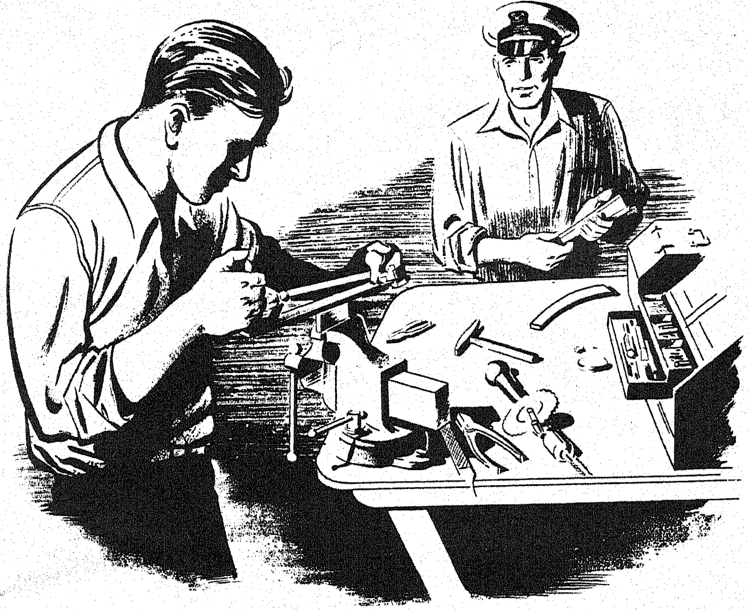
3. An organization made up of two or more divisions of vessels is known as a—

(*a*) Fleet.

(*b*) Squadron.

(*c*) Flotilla.

(*d*) Section.



CHAPTER 2

TOOLS AND EQUIPMENT

The infantryman keeps a clean rifle. His rifle is his tool. The navigator depends upon his compass, chronometer, and sextant. Detailed care, maintenance, and operation of these—his tools—make modern navigation possible.

Your tools are just as important to you. Without them you will be unable to do your job. Keep them clean, keep them properly stowed, keep them in tiptop condition.

BREAK OUT THE GEAR

Break out the gear with which you are going to work. Much of it is familiar. There are special tools, however, with which you may not be familiar. It is with some of these that this chapter is mainly concerned. Other tools are discussed in later chapters. Study the illustrations and the discussions. Get

clearly in mind the purpose of a tool then go into the shops and watch the man who uses it. Ask questions—intelligent questions—and you will find the Chief and First Class Metalsmiths competent and willing to help you.

When you have reported aboard your first ship or station, been cleared by the O.O.D. and assigned to a division by the Exec or the Personnel Office, your division officer will have a bunk and locker assigned to you. You'll then most likely report to the PO in charge of the shop in which you'll work. He'll give you the dope on the time and place to fall in for morning quarters, working hours, chow, liberty, watches, and on the duties you will perform. As a rule, he'll give you the general shop routine and let you know what is expected of you. In the course of the conversation he'll get some information from you—where you came from, the experience you've had, the progress you've made on training courses, and that sort of thing. After that little confab, you'll probably be given the rest of the day to square away your gear, get the feel of the ship, and get settled. You probably won't have to report back to the shop until the next morning. That's when you'll start getting squared away in the shop.

YOUR OWN TOOL KIT

Some shops are set up so that each Metalsmith has a tool kit of his own; others operate from a central tool room. In either case, there are certain tools that have a more or less personal nature. Tools of this kind are scribes, prick punches, small screw drivers, dividers, scales, and steel tapes. You might borrow and use your shipmate's razor, comb, or even his towel if the need arises, but you certainly wouldn't use his toothbrush. Some tools fall into the same personal category. Be just as particular with your tools as you would with your toothbrush. Keep those tools clean and in good condition. When they are not in use, protect them from the rusting effect of salt air by covering them with a light coat of machine oil.

The following is a Metalsmith's Tool Kit as taken from an allowance list for Fleet Repair Ships:

Tool box, mechanics, steel, individual, empty for the following tools:

One hammer, bumping, 16 oz.
One hammer, tinners', raising, 28 oz.
One hammer, tinners', riveting, 16 oz.
One hammer, tinners', setting, 12 oz.
One mallet, coppersmiths', $3\frac{1}{2}''$ diameter.
One mallet, tinners', $2\frac{1}{2}''$ diameter.
One mallet, tinners', $3\frac{1}{2}''$ diameter.
One punch, center $\frac{1}{2}''$, round or octagon.
One punch outfit, metal, suitable for punching $\frac{1}{4}''$ holes in No. 16 gauge sheet iron. Each outfit shall consist of one punching tool together with three standard punches and three standard dies, one each of the following sizes: $\frac{1}{8}''$, $\frac{3}{16}''$, and $\frac{1}{4}''$, and four special dies on each of the following sizes: $\frac{1}{16}''$, $\frac{3}{32}''$, $\frac{5}{32}''$, and $\frac{7}{32}''$.
Rivet sets and headers, type II, ranging in size from 00 to 8.
One shears, tinners', hand, straight cut, type A, 3''.
One shears, tinners', hand, circular cut, $3\frac{3}{8}''$, type B.

The tools listed in the preceding allowance list are only a small portion of the tools that you will have in your tool box. As time passes, you'll acquire and draw from Supply additional tools that you will need.

Some of these extras may be layout tools, such as a scribe, dividers, calipers, triangles, protractor, trammel points, and a 12- or 18-inch steel scale. Probably along with these you will have a piece of soapstone metal marking crayon. You'll use the soapstone when you are laying out on steel plate and shapes.

Other hand tools that you may some day have in your tool box are: CHISELS—cold, cape, round nose, and diamond point; TAP WRENCHES and TAPS—taper, plug and bottoming; a BREAST DRILL, STRAIGHT SHANK NUMBER DRILLS, PLIERS, NIPPERS, a SPARK IGNITER, SCREW DRIVERS, COUNTER SINKS (30° and 60°), and ADJUSTABLE OPEN END WRENCHES.

If it were possible for you to carry all of the available hand tools that you would at some time or other need in the work that you will be called upon to do, you'd have to have a tool

box almost as large as the main GSK on a destroyer escort. The type of work that you will do most often will determine the tools that you will have in your tool box. For example, if you are assigned to the welding shop, you will have a stinger, flash goggles, slag hammer and brush, cleaning drills for your cutting-torch tips, gloves, hood, and protective clothing.

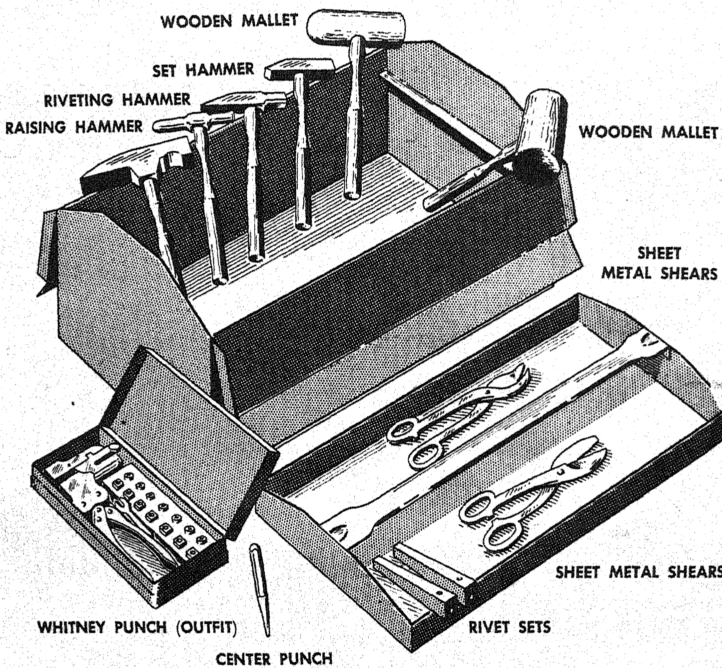


Figure 5.—Tool kit.

Maybe you'll be a sheet metal worker, a blacksmith, or a Doall operator. If you are a jack-of-all-trades on a PC Boat, you're going to have a different set of tools than those you would have if you were on a Fleet Repair Ship doing a specialized type of work. Study your Basic Navy Training Course, *Use of Tools*, NavPers 10623. That book will give you the dope on all the hand tools you'll be required to use.

The most important things to remember about all of your

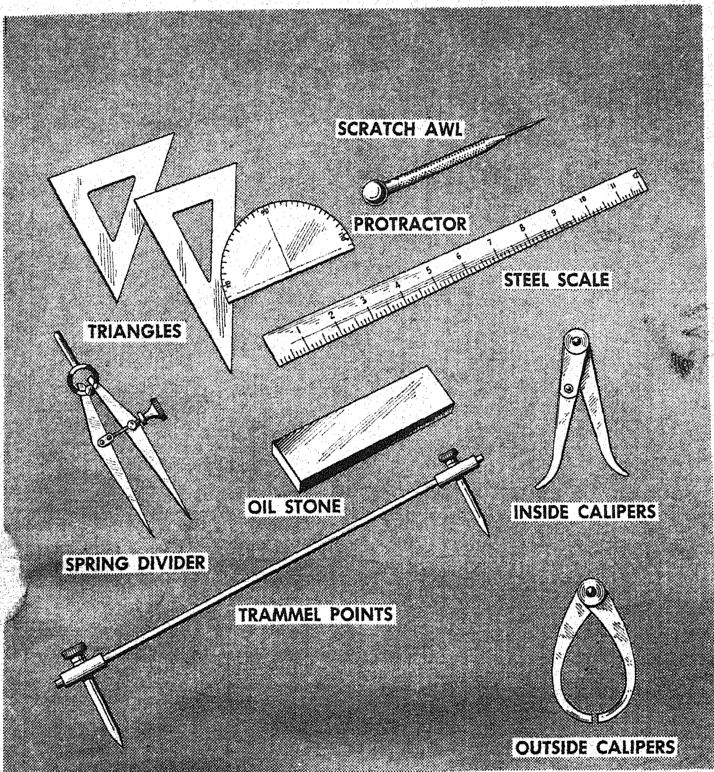


Figure 6.—Layout tools.

tools, whether they are hand tools that you have in your tool box, special-purpose tools that you will check out of the central tool room, or shop tools that you and your shopmates use as needed, are these: USE A TOOL FOR THE PURPOSE FOR WHICH IT WAS DESIGNED, KEEP IT CLEAN, AND KEEP IT IN TIPTOP CONDITION.

SPECIAL PURPOSE COMMUNITY PROPERTY TOOLS

There'll be times when you will have to go some distance from your shop to do a job. If the job is small and simple in nature,

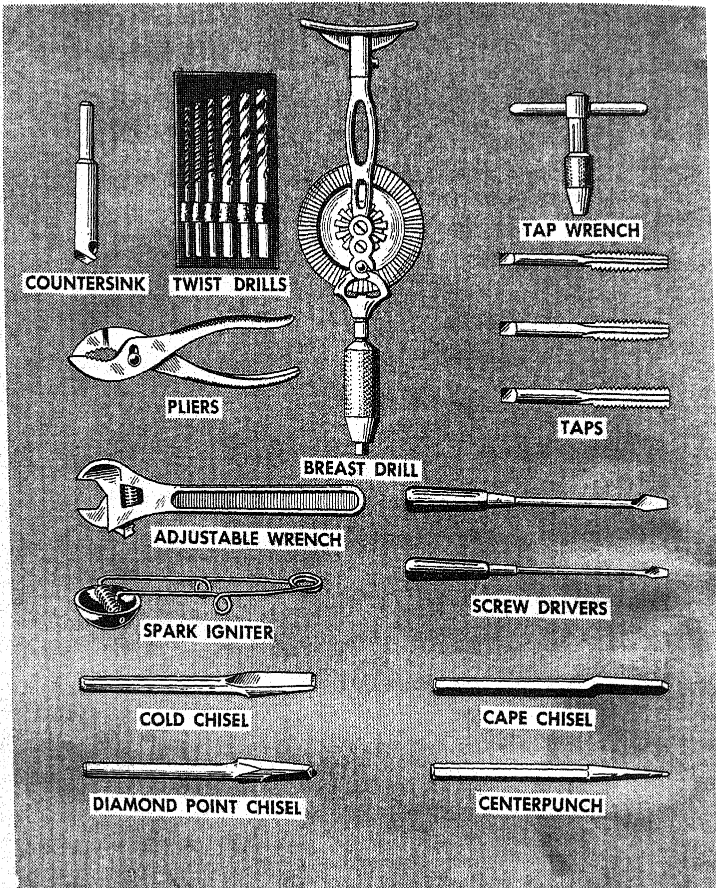


Figure 7.—Additional hand tools.

you may need only a pair of gas pliers, a screw driver, or a hammer.

Many of the repair jobs you have to do will require the use of only a few tools; others will require many tools. It would be a simple matter if the tool box assigned to you covered every application of work. All you'd have to do then is pick up your tool box and do the job without having to think about what tools you would need.

You will often need special-purpose tools that are rather bulky—tools that wouldn't fit into your tool box even if they were assigned for your personal use. These bulkier tools are generally stored in a central tool room, or in some convenient location in the shop, where they are available for the use of ALL MEMBERS of the shop as needed.

Tools in this category are: Drill motors, portable grinders, pneumatic chipping guns, pinch bars, sledges, socket wrenches, steel squares, bolt cutters, blow torches, soldering coppers, clamps, wedges, screw jacks, portable welding outfits, and stock and dies for cutting machine threads.

Your bench vise will be one of your most useful tools. You'll use it in the shop and on occasion you'll set up a vise on the job. You'll have hundreds of uses for the vise to secure your work for drilling, bending, filing, and holding operations. There are several kinds of vises which you might have aboard. You'll have a general purpose utility vise and probably a pipe vise.

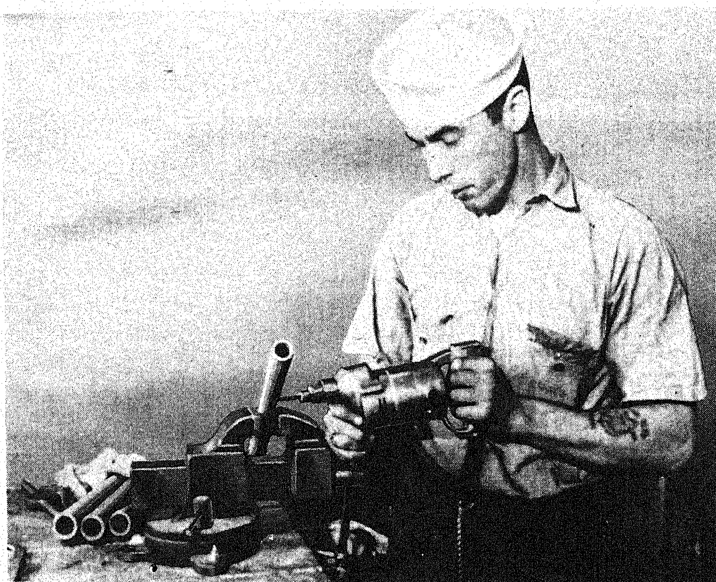


Figure 8.—A vise and electric drill in use.

Drill motors, either electric-powered or air-driven, will be available in sizes from ¼-horsepower to 1-horsepower motors. The small sizes operate at relatively high speeds, while the larger sizes are geared to drill larger holes at a speed slow enough to prevent the burning of the drill bit.

In general shop work, there won't be many days that you'll get by without drilling some sort of a hole in metal. Probably the most important point in drilling a hole, whether you use a drill press, hurdy-gurdy (breast drill), or an electric or air motor, is that the drill bit is sharp and properly ground. Figure 9 illustrates a properly-ground twist drill.

Some shops and tool rooms are equipped with drill holder fixtures to facilitate sharpening drills properly. If you have this tool, be sure to use it. It takes the guess work out of sharpening. Otherwise, you'll have to sharpen the drill by hand.

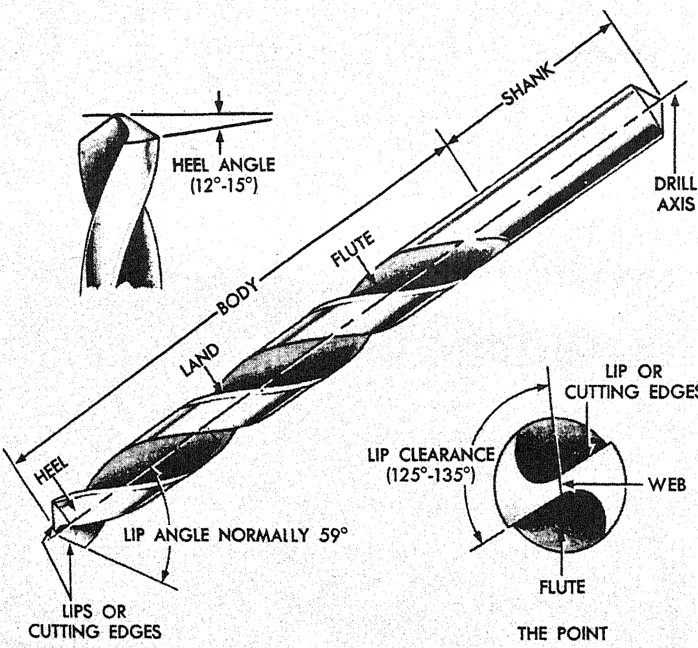


Figure 9.—Twist drill.

You'll have to be careful. Both cutting edges must be ground to the same angle to the axis and be the same length. If they aren't, you're going to have difficulties—too much strain placed on one cutting edge, and you're likely to burn the point or break the lip. In either case, the tool will have to be reground. Some other troubles caused by improperly-ground drill points are enlarged holes, drilling off center, and slow cutting.

You'll need clamps with a lot of your work. You'll use them to hold sections in position for drilling, riveting, bending and welding. The clamp you will most often use is the C clamp shown in figure 10.

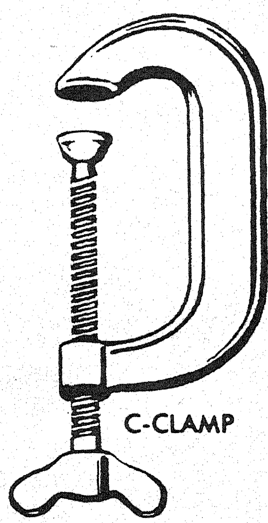


Figure 10.—"C" clamp.

There are several kinds of C clamps, in a number of sizes. There's not much maintenance on a clamp. Keep the screw lubricated and free of rust just as you would any other tool.

You'll probably cut internal threads with a TAP more often than you'll cut external threads on a piece of stock with a DIE. Taps and dies are very hard and brittle, and they don't have a great deal of resistance to shock. For that reason you'll have

to be very careful how you handle these tools. Take it easy when you cut threads with them. Be sure that you keep the work well-lubricated. A bar of salt water soap is a good lubricant. Just push the tap down into the bar of soap before you start to cut the threads.

Your tool room will have a chart which will tell you what size drill to use for every size tap. A hole drilled for tapping out will be smaller than the tap, while a clearance hole will be larger. When you start to cut the internal thread, be sure that you have the tap started properly. Aline the tap with your eye or use a square. Whichever way you do it, be sure that you get the tool started properly or you'll have a set of crooked threads.

When you cut external threads, you have to take the same sort of precautions to insure that the die is started straight and the tool kept lubricated during the cutting operation. You'll use a cutting oil as a lubricant with the die. Don't try to cut the threads in a continuous operation. Work the tool forward and backward, cutting the threads a little at a time. This will permit the chips to work out and insure a clean-cut thread.

If you should have the misfortune to break a tap, don't let it worry you too much. This has happened to the best Metalsmiths at least once. After removing your first broken tap, you won't want to repeat the experience. When you do have to remove a broken tap, you can often do it by using a blunt cold chisel or a punch as illustrated in figure 12. After the tap has been started out, you can finish removing it with a tap extractor.

In the shop and out on the job you'll make the sparks fly with a portable grinder to grind down welds, dress rough cuts, and to prepare broken stationary-machinery castings for welding or brazing. Be sure that you WEAR PROTECTIVE GOGGLES in all of your grinding and chipping operations. The portable grinder that you have may be powered by an electric motor or by an air turbine. Whether electric- or air-powered, the use of the tool is the same. Give it the same general care you would any other hand or power tool. Keep it lubricated, keep it clean.

Pneumatic tools must have thorough lubrication. The

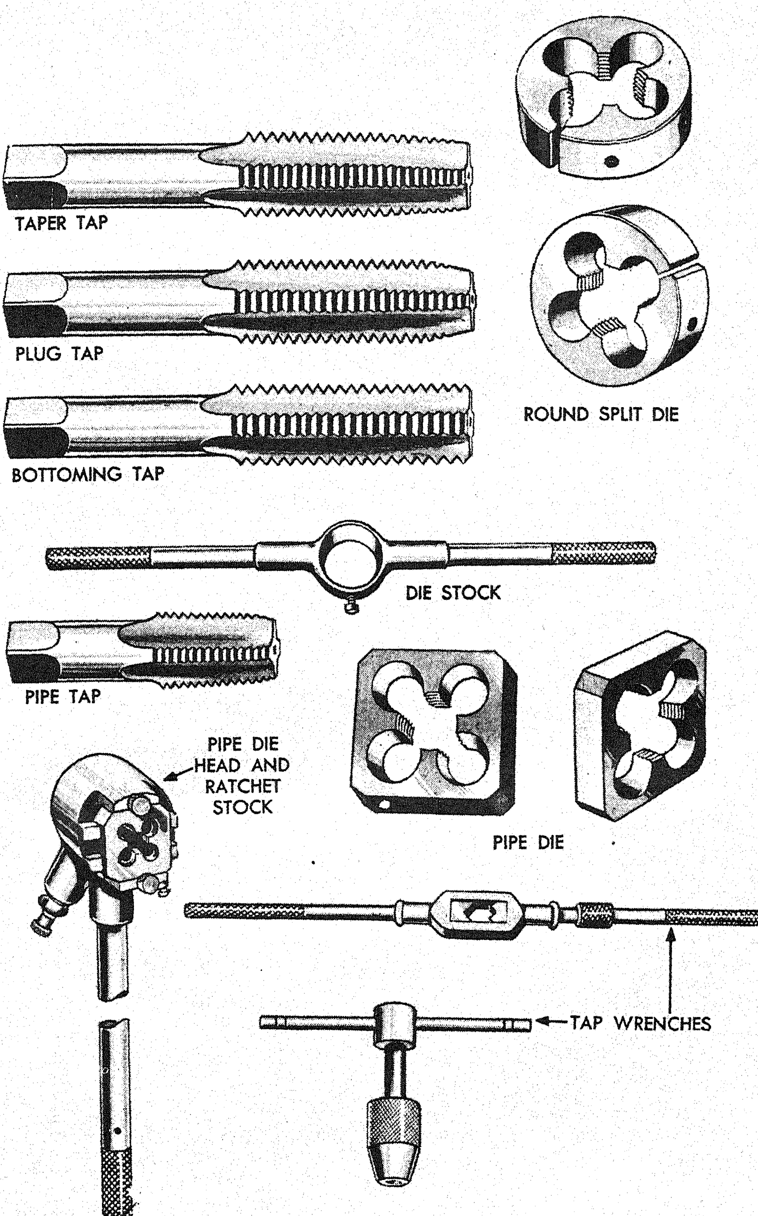
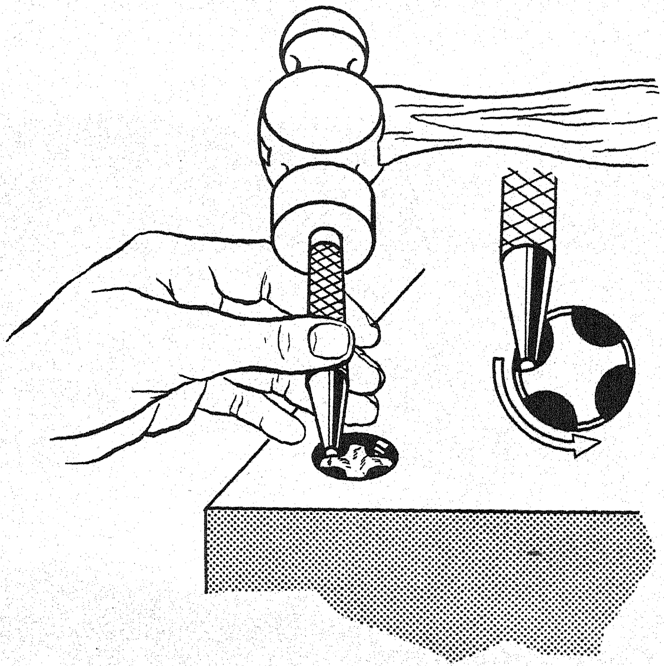


Figure 11.—Taps and dies.

moving parts of a pneumatic tool are very closely fitted, and if proper lubrication is neglected, they wear rapidly and in a short time refuse to work.

Valves and pistons on pneumatic hammers require a light



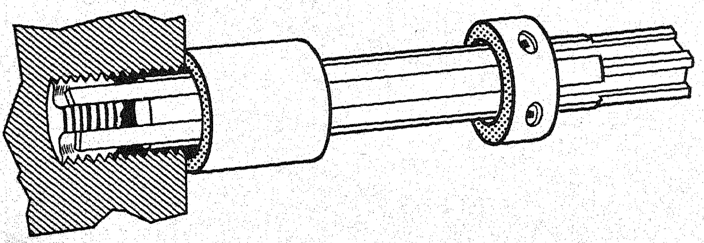


Figure 12.— Removing a broken tap with a tap extractor.

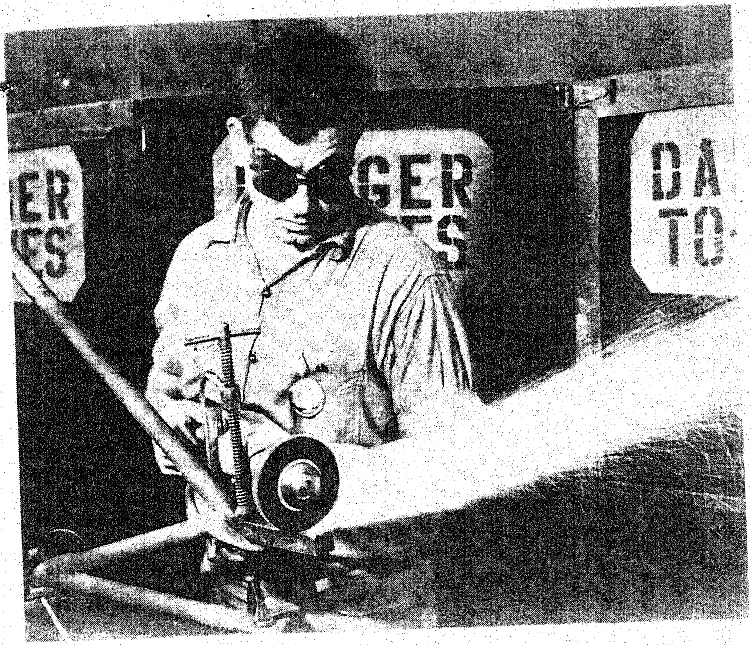


Figure 13.—Using a portable grinder.

machine oil, and as the compressed air comes directly in contact with these parts, it has a tendency to drive the lubricant out through the exhaust.

When working constantly, you should disconnect the air hose every hour or so and squirt some oil into the air-hose connection. Don't use heavy oil, or you'll "gum up the works" and have operating troubles. If this happens, you'll have to clean your tool in gasoline or benzine to loosen the gummy substance. Blow out the tool with air, lubricate with a light oil, and go back to work.

Keep your pneumatic tools clean and lubricated and you won't have operating troubles.

MACHINE TOOLS

The heavier stationary machine tools will vary with the mission of your ship or station. A vessel designed to patrol

harbors will not be equipped with more than a few lightweight machine tools. On the other hand, a Fleet Repair Ship will have many heavy metalworking machines.

Regardless of the size of your ship, you'll probably have a slitting shear, drill press, bench grinder, welding machine, oxyacetylene outfit, and several sheetmetal rotary machines.

Aboard repair ships and bases, you'll have these machine tools plus a lot of heavier machinery. You'll see and use a POWER SLITTING SHEAR, a POWER HACK SAW, a POWER BENDING BRAKE, a UNIVERSAL IRON WORKER, a POWER COMBINATION ROTARY MACHINE, a THROATLESS SHEAR, a MARVEL SAW, POWER-FORMING ROLLS, a DOALL, POWER PUNCHES, a WELDING POSITIONER TABLE, a STATIONARY WELDING PANEL, and a PIPE BENDER. These heavy capacity machines will help you do work that would otherwise be very difficult. With the machines you can do your job a lot better and a lot faster.

Your slitting shear will prove very useful when you have cuts to make on heavier gauges of sheet metal. That is, when you don't have a squaring shear to make long cuts. The thicknesses of metal between 14 gauge and 1/8th inch could be called the "awkward gauge." It's too heavy to cut with hand shears, too difficult to cut with bench shears, and too thin to "burn" with an oxyacetylene cutting torch and do a good job. You'll use the slitting shear most often as illustrated in figure 14, to cut strap iron and flat bar.

You can make all sorts of jury rigs to help you make bends in pipe and strap iron, but a bending slab with guide posts and clamps as illustrated in figure 15 will solve many of your bending rig problems. There isn't much upkeep on a bending slab. It's cast iron though, so don't test your swing power with a sledge hammer on the slab or you may crack it. Coat the surface of the slab with light machine oil to keep the rust in check.

You may have a drill press that is larger than the model illustrated in figure 16, or you may have one that is smaller in size. Large or small, you'll use it to do the same type of work. In addition to drilling holes with the press, you can also cut medium-sized circles in sheet metal by attaching a hole saw

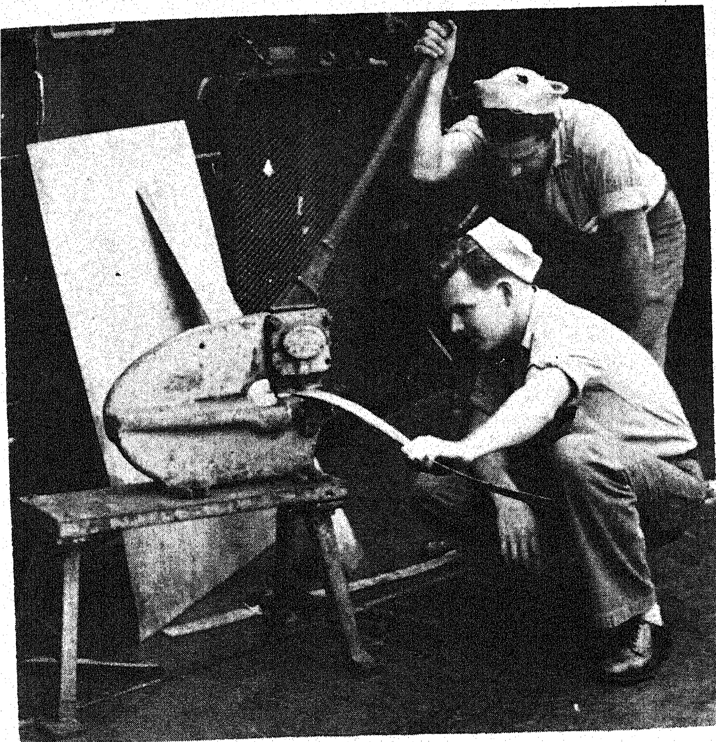


Figure 14.— Cutting strap iron with a slitting shear.

instead of a twist drill. You remember the hole saw from your basic course, *Use of Tools*, NavPers 10623. You'll have to be certain that your work is properly secured to the table before you start drilling. Don't make adjustments while the drill is running. Be sure to use a lubricant, and follow the manufacturer's recommendations when you set up your press.

One of the most useful all-round machine tools in your metal working shop is the UNIVERSAL IRON WORKER. This machine is illustrated in figure 17. Most of the shipboard models are smaller in size, but you may see this particular machine at the larger shore stations. Work can be done on both ends of the machine at the same time. However, you can't do two jobs on the same end of the machine at the same time.

You'll use the slitting attachment in the same manner that you do the hand-operated slitting shear. To help you make the cuts just where you want them, you'll clamp your metal securely in position with a stripper plate or holding device.

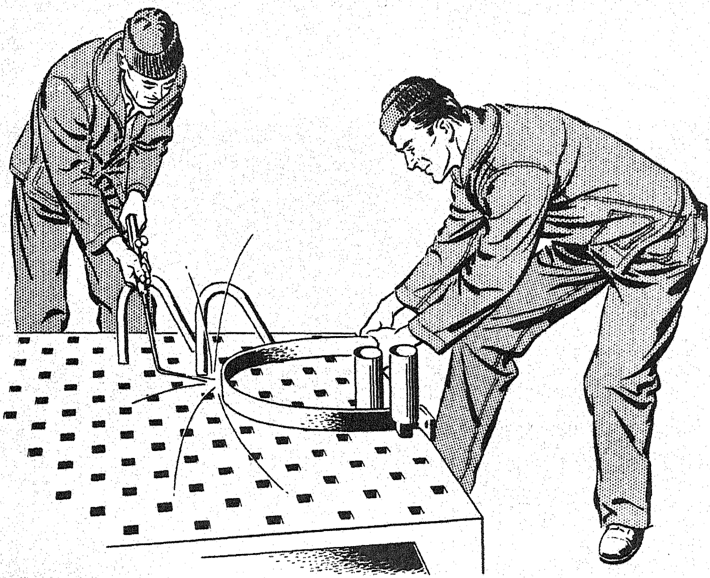


Figure 15.—Bendina slab.

If you have never hacksawed angle bars to desired lengths or "veed out" notches for bending angle bar frames by hand, you may not appreciate the amount of manual work the machine with its angle bar shear, notcher and coping attachments, relieves you of. All you do is to trip the foot pedal, and crunch—the cut is made. That's a lot simpler than sawing through at 40 strokes a minute.

All machines have a maximum capacity, and the universal ironworker is no exception. The capacity plate on the side of the machine will tell you what thickness of bars, round stock, and plate the machine will handle. Follow the manufacturer's instructions for maintenance, greasing, oiling, and upkeep.

You'll have a lot of use for the punching head of the universal

ironworker, but on lighter sheets of metal you'll more often use a hand punch similar to that in figure 18. The TURRET PUNCH has 12 punches and 12 dies mounted in turrets. With

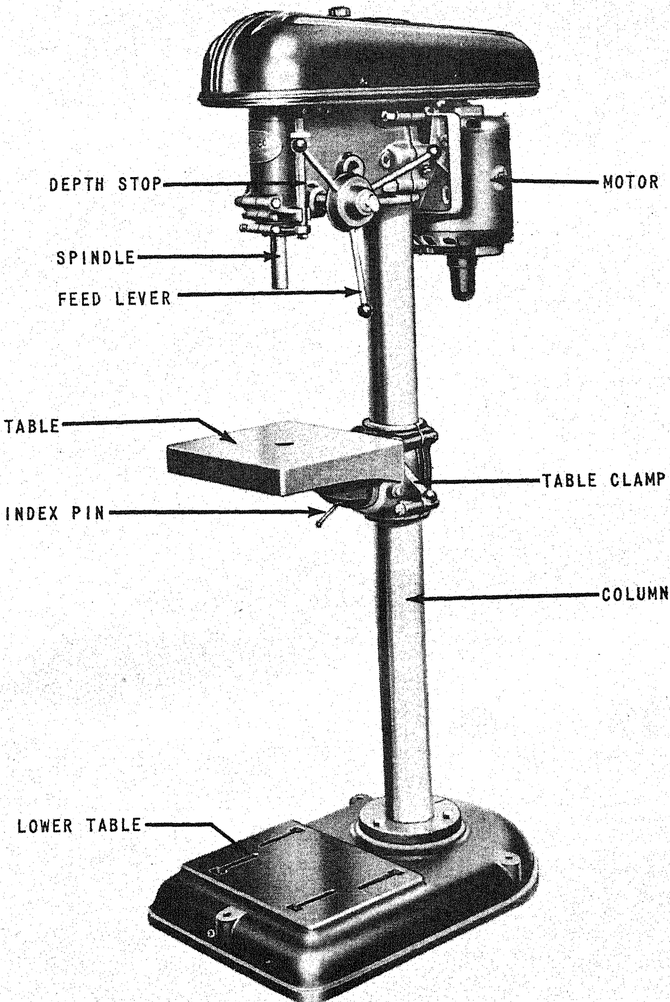


Figure 16.— Drill press.

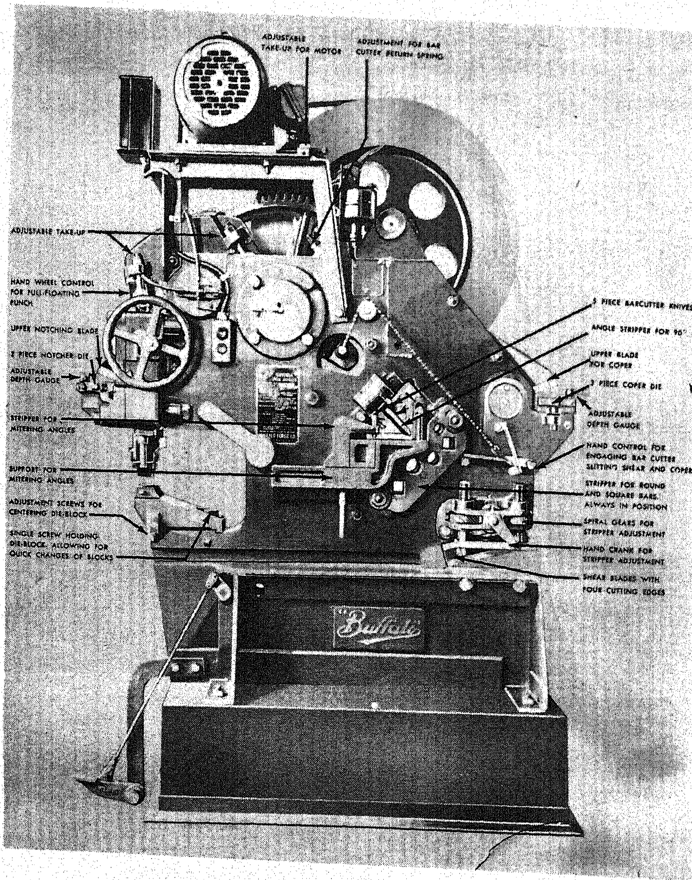


Figure 17.—Universal iron worker.

this machine you can punch holes up to 1¼-inches in diameter. To engage the desired punch with the ram, release the locking handle on the side of the punch and rotate the turret until the desired punch engages the ram. Lock the turret in position with the locking handle and punch your hole.

Each die block has the size of the hole it will punch and the maximum-capacity thickness of metal it will penetrate stamped on the front. These capacities are for mild steel, so you'll have

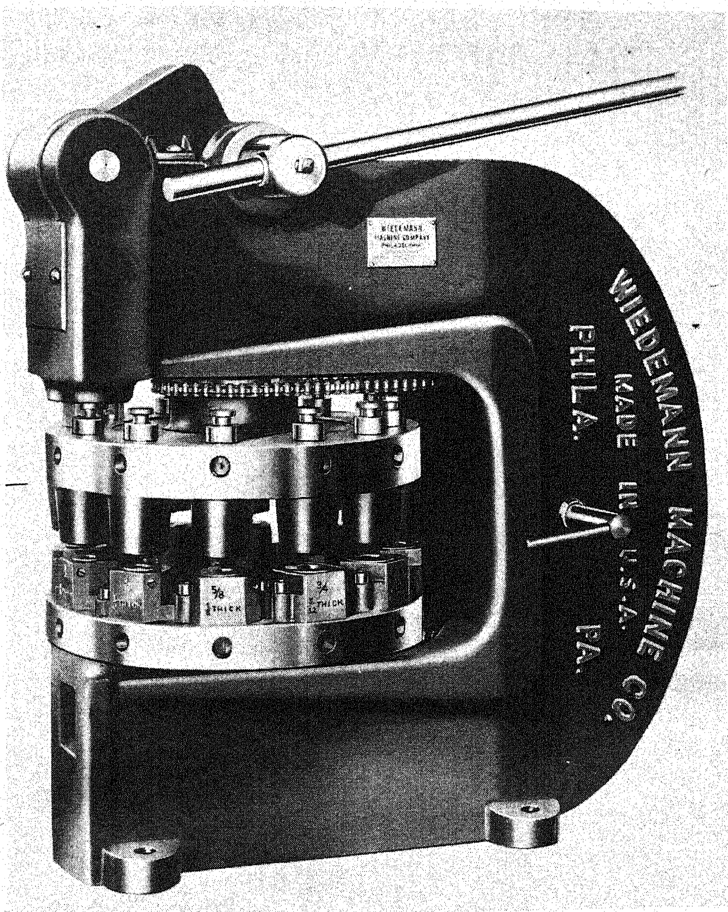


Figure 18.—Hand-operated turret punch.

to bear that in mind when you want to punch stainless or other alloy sheet.

Holes cannot always be drilled, punched, or sawed. Quite often you'll use a portable oxyacetylene outfit for piercing holes. Your shop may be set up with several of these outfits. You might have a different rig for your welding and cutting equipment than the one illustrated, or you might have several sets rigged in a permanent setup. Whether or not your equip-

ment is portable, you'll use it in the same way. In addition to welding and brazing, you'll cut plates and angles to shape and size with a cutting torch. You'll see this rig used daily around the metal shop. So much of your work will deal with welding and cutting that separate chapters covering that phase of your work are included in this book.

Instead of the heavy-duty, ¼-inch-capacity throatless shear illustrated in figure 20, you might have a smaller power- or

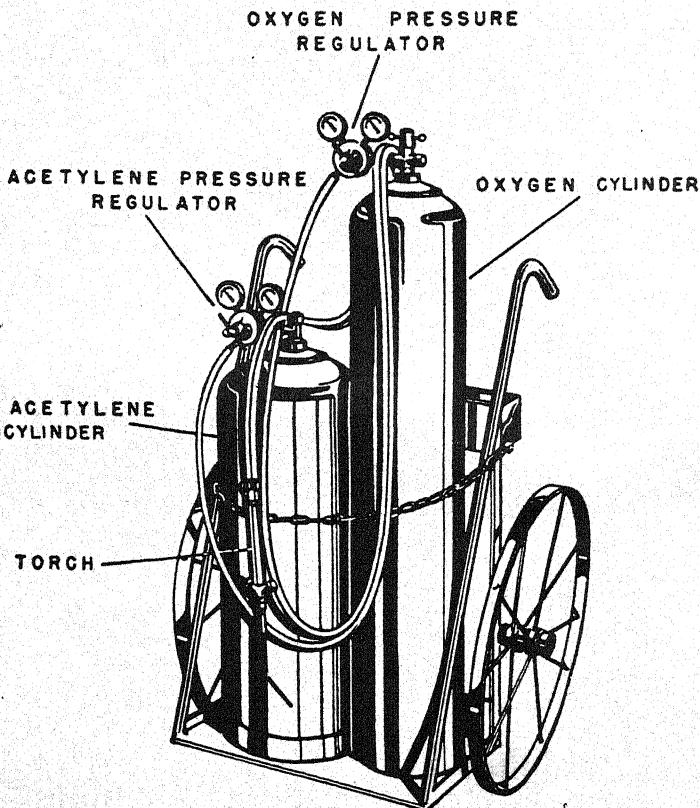


Figure 19.—Portable oxyacetylene equipment.

hand-operated model. Other than the capacity metal that can be cut in the shear, the type of work that can be done with the smaller type machine is the same. You'll use it most often for cutting out shapes that have an irregularly curved edge such as that of an elbow pattern. There are no guides to help

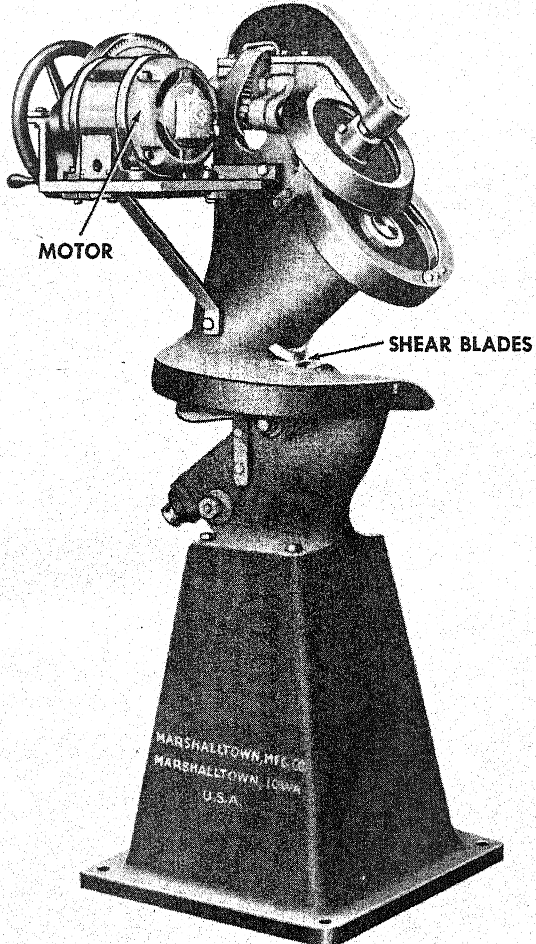


Figure 20. — Throatless shear.

you. You'll control the cut by changing the dire᾿ ... ᴊᴏn
sheet to follow the contours of the line. ... shape

When you have to roll or form cylindrical s ... used daily
tion ducts or the body of a tank, you'll use ... will deal with
If the gauge of metal is light, you won't have u ... covering that
power rolls shown in figure 21. Imagine the tro
into forming a cylinder out of a sheet of ¼- ... roatless shear
metal if you didn't have a forming machine large ... er power- or
that sort of work.

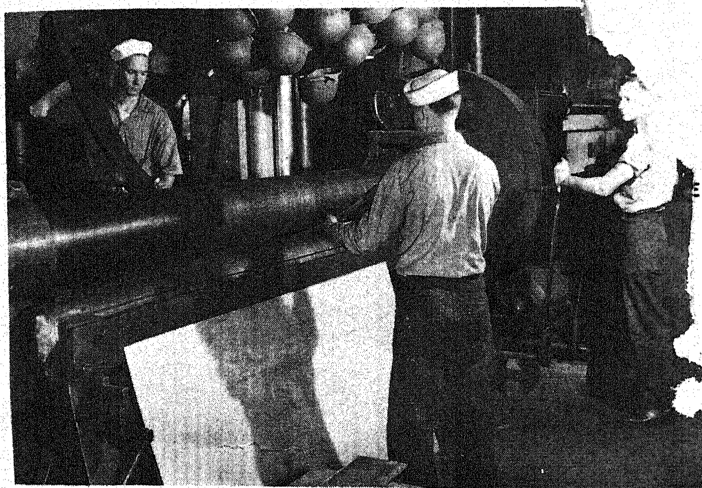


Figure 21.— Power slip-forming rolls.

You won't see a shop or tool room that doesn't have a bench- or pedestal-type grinder. You'll use it to sharpen tools and dress edges. Always use the safety shield and safety goggles when you have any grinding to do. The chapter on ABRASIVES in your *Use of Tools*, NavPers 10623, will give you all the dope on bench grinders.

You'll have some hand-operated turning machines for flanging, burring, and beading sheet-metal shapes. These machines and their operation are discussed in chapter 11. Some large ships, and all tenders and repair ships, have a power-

combination machine with a flanging attachment be cut the one illustrated in figure 22. Your shopmates smaller t ow to change the dies and how to set up the for cutting ou many operations it will perform. The hand-such as that ing machines will probably be easier for you to til you get the knack of working your metal in the es. After you get the knack, however, you'll e a do the job a lot faster on the power machines, par-iculalry when you work with heavy-gauge metal.

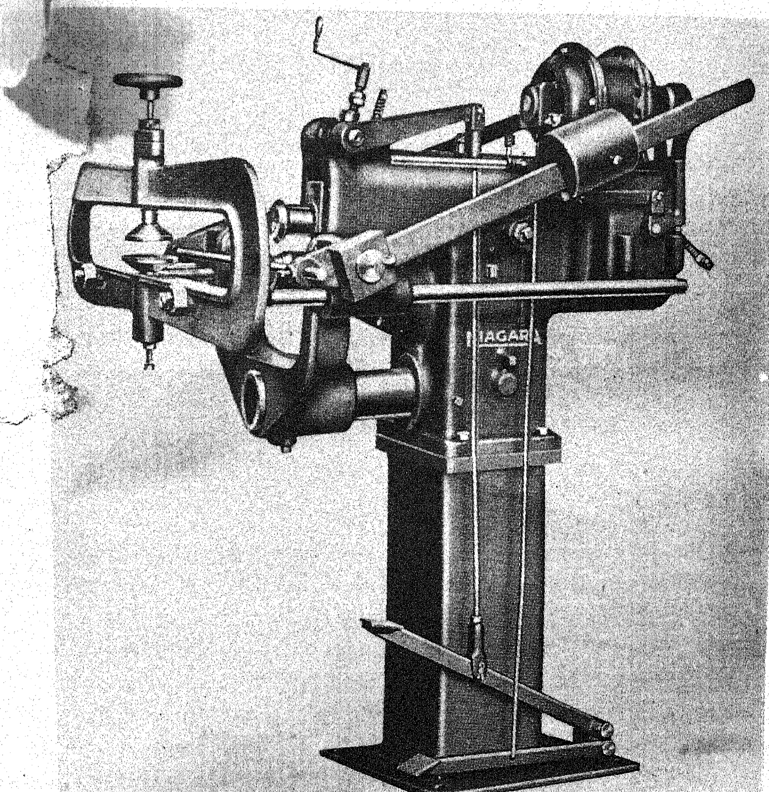


Figure 22.— Power combination machine.

Your friend the pipefitter will be using a pipe bender more often than you will. In fact, the pipe-bending machine will be located in his shop, but there will be times when you'll bend sections of pipe to make hand rails or guard rails. When you have this type of a job to do, you'll probably help the pipefitter make the bend on a machine similar to the one illustrated in figure 23.

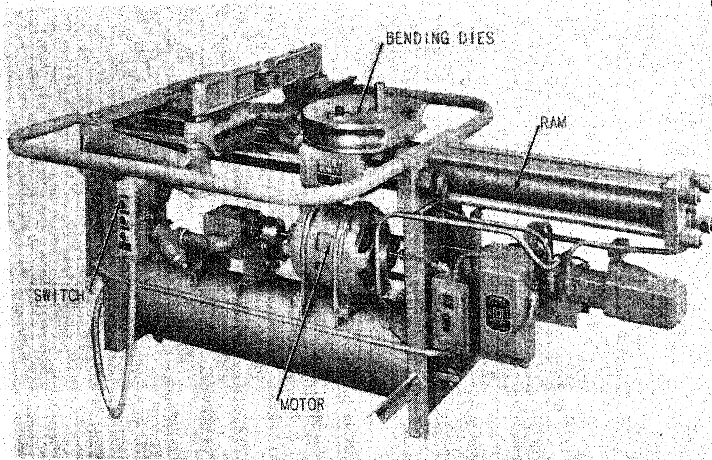


Figure 23. — Power pipe-bender.

Much of your bending, particularly in sheet-metal and plate work that requires 90° bends or other bends with sharp radii, will be made in either a hand- or power-operated metal-bending brake. The power models similar to that in figure 24 have capacities for heavy-gauge sheet and plate, while the small hand-operated brakes discussed in chapter 11 are limited to 14 and 16 gauge.

You are probably familiar with the flashes of light that come from the business end of an electric welding stinger when the weld is being made. Maybe you have given some thought to the source of power that makes welding possible. Your welding

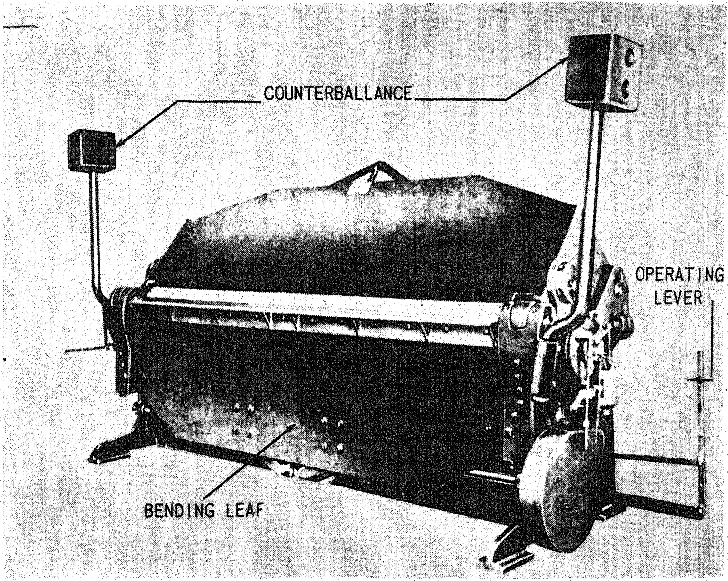


Figure 24.— Power bending brake.

equipment for electric arc welding processes may range from small portable 150-amp. motor-generator sets to the 750-amp. constant potential stationary motor generator shown in figure 25. This set is usually found on large vessels and repair ships. On some of the tenders you'll have large portable Diesel or gasoline motor generator sets, as well as alternating current (a.c.) welding outfits.

The individual portable outfits won't confuse you. You'll know what they are as soon as you see them. But the first time you see a stationary constant-potential welding panel you might wonder "what gives." Only one welder can work from the portable outfit, while several welders can work from the stationary panel. Your Chief or leading First Class Metalsmith will instruct you in the proper method of starting, adjusting, and stopping the motor generator.

The juice from the generator is transmitted to individual welding control panels where you will adjust the current to the

heat you want for a particular job. The welding current is selected by opening or closing the series of switches shown in the illustration. For example, if you want 50 amperes, consult the switching table in the panel box and close the switches indicated in the table—in this case, switches 1 and 3.

Another piece of machinery that you might see in the welding shop is a welding positioner-table. There's nothing complicated about this table. You'll secure the work to be welded to the

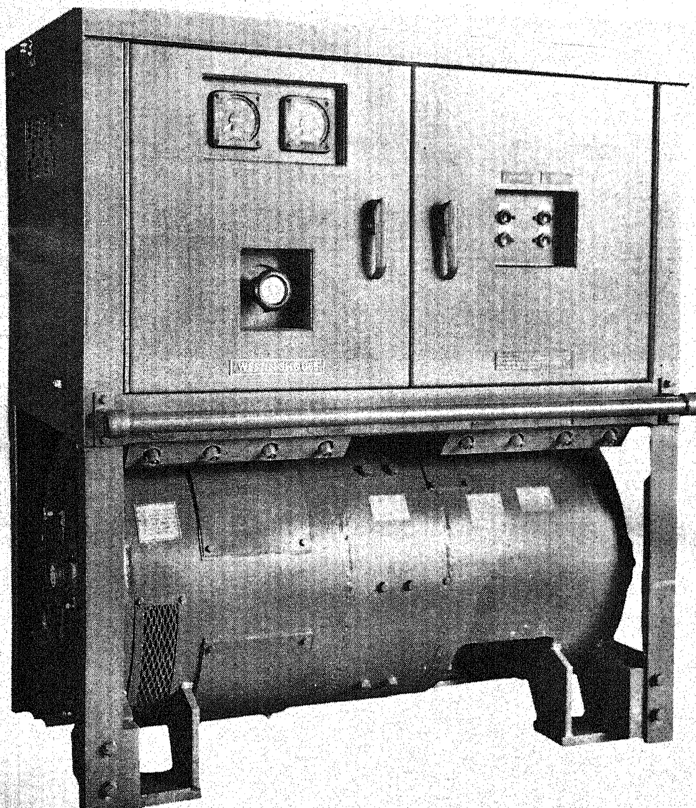


Figure 25.—750-ampere constant potential welding set.

table with "Tee slot bolts." To bring the weld area into a horizontal position tilt the table top.

At some time or other you'll be looking for material to make yourself a knife. One of the best steels for this purpose is the saw blade from a power hacksaw. Some of these blades are manufactured with only the saw teeth composed of tool steel, but others are tool steel throughout the entire blade. You'll have to be sure that you have the right kind of blade before you start on your knife. Another point to watch is this: that

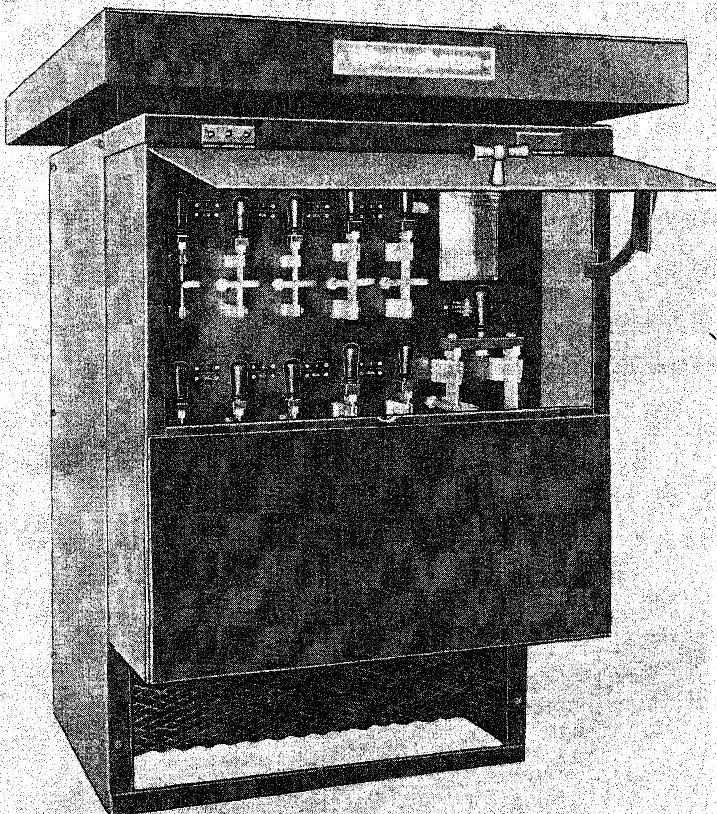


Figure 26.— Welders control panel.

the blade you choose has seen a lot of service and use in a power saw similar to the one illustrated in figure 28.

You'll use this saw frequently to cut lengths of angle and bar stock. This saw has a vise to hold your work securely in place while the saw is in operation. Be sure that you set the stroke speed and feed properly for the work you are cutting, and don't forget to keep the work well lubricated.

The Marvel metal cutting band saw illustrated in figure 29

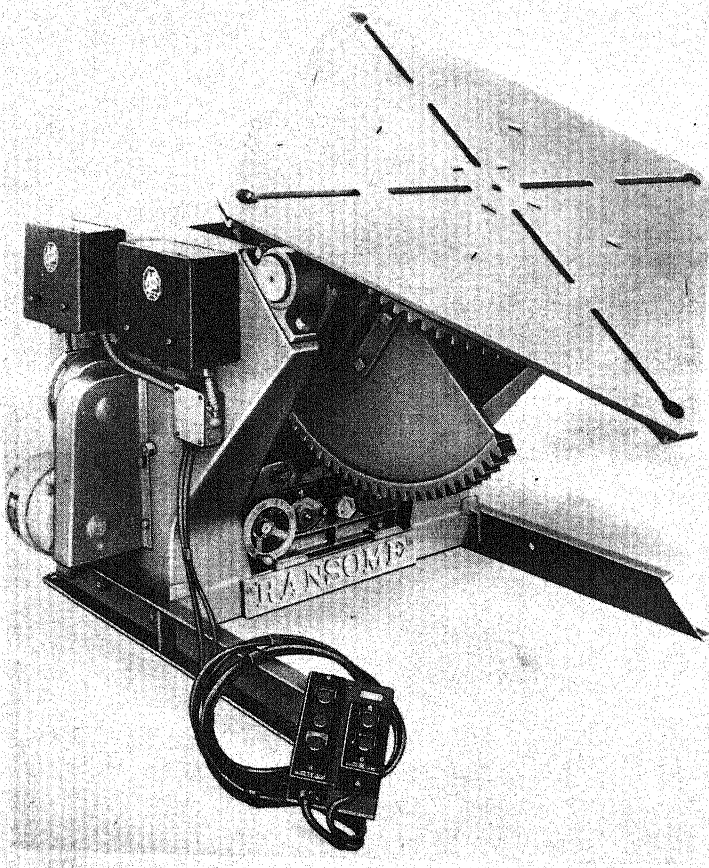


Figure 27.— Welding positioner.

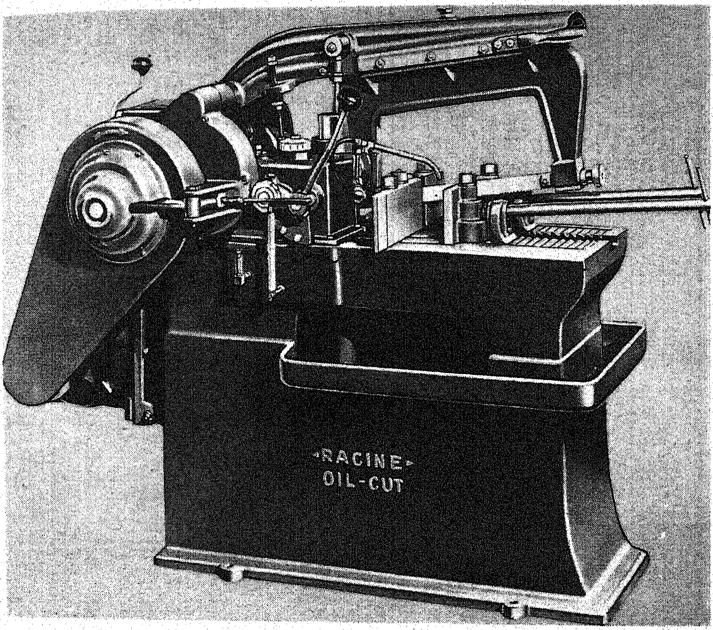


Figure 28. — Power hacksaw.

can be adjusted to make cuts at any angle to the table top. You will find this saw used frequently when elbows with thick wall sections have to be fabricated. A cylinder of the proper diameter is formed on the forming rolls and the seam is then welded. The cylinder is secured to the saw table, the necessary angle is set on the band saw column, and the miter is cut. The blade and piece being cut must be well-lubricated. All you'll have to do is open the valve to the lubricating tube and the lubricant is automatically pumped from a reservoir in the machine. Feed pressure and blade speed must be regulated for each job requirement. For specific instruction on operation and maintenance, ask your shop CPO to show you the manufacturer's instruction manual.

A DoAll machine shown in figure 30 won't serve for every metal working job that you'll have, but it will do a lot of jobs for you. The more you know about this machine, the more work

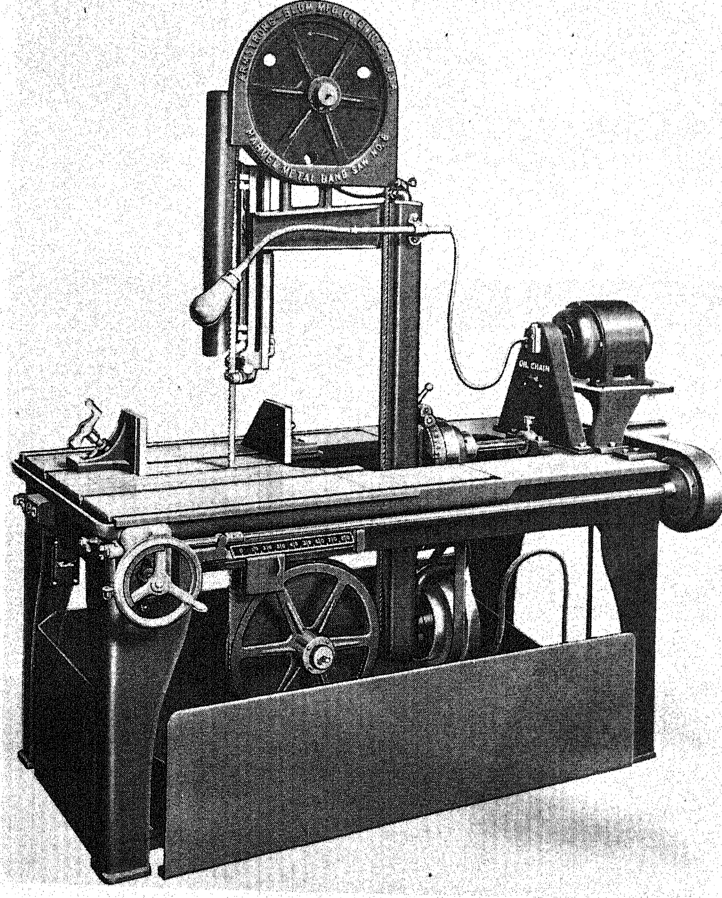


Figure 29.—Marvel metal cutting band saw.

you'll be able to do on it. Most of your work on this machine will deal with irregular curves on the inside of a blank, as well as curves on the outer edge of the stock. You can make an inside cut in a metal sheet with this machine in the following manner.

1. Drill or punch a hole in the sheet large enough for the saw blade to pass through.

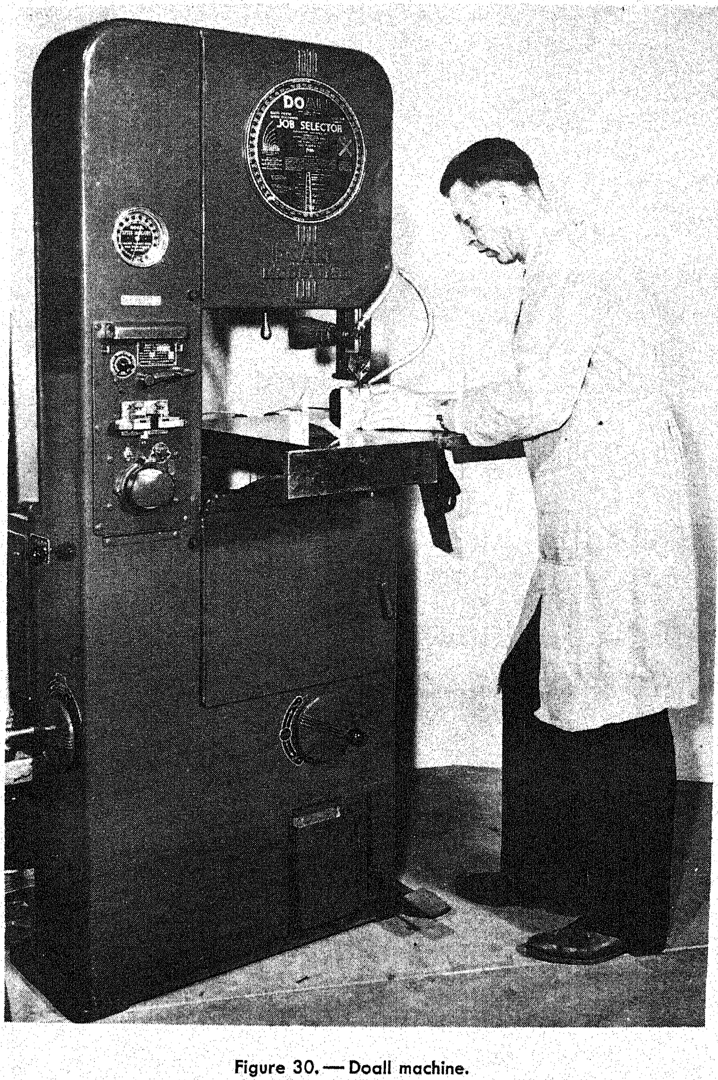


Figure 30.—Doall machine.

2. Cut the saw blade and pass the blade through the punched hole.

3. Weld the saw blade together in the butt welding attachment.
4. Grind down the weld in the flash grinder.
5. Replace the blade on the driving wheels.
6. Set your speed control and make your cut.

You may be assigned to a ship that has all of the machines and tools that have been discussed or you may be aboard a ship that has only a few of them. In either case, you'll be working with the machines and taking care of them. Machinery and tools, like fire, can be your best friends if used properly and with common sense. Use your tools for the purpose for which they were designed and within their rated capacity. Treat them right and they'll do right by you.

QUIZ

Select the one best answer to each of the following statements.

1. For tools which are not in use, the recommended protection against corrosive effect of damp salt air is to —

   (*a*) Place in a kerosene bath.
   (*b*) Wrap in oil paper.
   (*c*) Coat lightly with machine oil.
   (*d*) Seal in an air tight container.

2. The metal punch outfit, usually found in a Metalsmith's Tool Kit, is suitable for punching holes in No. 16 gauge sheet iron up to a diameter of—

   (*a*) ¼-inch.
   (*b*) ⅛-inch.
   (*c*) ½-inch.
   (*d*) 1¼-inches.

3. A recommended metal marking crayon used for lay-out on steel plates will be made of —

   (*a*) Sandstone.
   (*b*) Chalk.
   (*c*) Soapstone.
   (*d*) Carbon.

4. The tool which is too large to fit into a tool kit and has to be checked out of a central tool room is usually referred to as —
   (*a*) A general purpose tool.
   (*b*) A stationary tool.
   (*c*) Land base equipment.
   (*d*) A special purpose tool.

5. A tool which would be classified as "community property" would be the —
   (*a*) Scriber.
   (*b*) Prick punch.
   (*c*) Small screw driver.
   (*d*) Portable grinder.

6. A tool used for holding work during such processes as drilling, bending, filing, etc., is the —
   (*a*) "C" clamp.
   (*b*) Slab.
   (*c*) Vise.
   (*d*) DoAll.

7. Drill motors, either electric or air, will be sized according to —
   (*a*) Revolutions per minute.
   (*b*) Horsepower.
   (*c*) Amount of current or compressed air required.
   (*d*) Chuck capacity of tool driven.

8. A properly ground twist drill will have a lip angle, normally, of —
   (*a*) 10-15 degrees.
   (*b*) 59 degrees.
   (*c*) 118 degrees.
   (*d*) 125-135 degrees.

9. A tool used for holding flat sections in position for riveting, welding, etc., is the —
   (*a*) Doall.
   (*b*) Universal Iron Worker.
   (*c*) Welding positioner.
   (*d*) "C" clamp.

10. Internal threads will be cut with a —
   (*a*) Tap.
   (*b*) Die.
   (*c*) Broach.
   (*d*) Milling machine.

11. External threads will be cut out with a —
   (*a*) Tap.
   (*b*) Broach.
   (*c*) Die.
   (*d*) Milling machine.

12. A good lubricant to use for cutting internal threads, if cutting oil is not available, is —
   (*a*) Soapstone.
   (*b*) Salt water soap.
   (*c*) Graphite.
   (*d*) Benzine.

13. The diameter of a hole drilled for tapping, in relation to the tap diameter, must be —
   (*a*) Larger.
   (*b*) Smaller.
   (*c*) The same size.
   (*d*) A close tolerance fit.

14. To insure a clean-cut thread, the tool should be worked forward and backward in order —
   (*a*) That chips may work out.
   (*b*) To keep tool properly aligned.
   (*c*) To allow proper cooling of material.
   (*d*) To eliminate lubricant.

15. A broken tap, if loose but below the surface, can be removed with —
   (*a*) A rotary magnet.
   (*b*) A screw driver.
   (*c*) A stud remover.
   (*d*) An extractor.

16. Proper lubrication may be maintained, when using a pneumatic tool constantly, by disconnecting the air hose every hour and placing in the hose connection a specified amount of —
   (*a*) A heavy machine oil.
   (*b*) Light machine oil.
   (*c*) Cup grease.
   (*d*) Graphite.

17. Gummy substance may be best cleaned from a pneumatic tool with —
   (*a*) Kerosene.
   (*b*) Prussian blue.
   (*c*) Lapping compound.
   (*d*) Benzine.

18. Strap iron which due to its thickness or thinness, can not be cut with hand or bench shears or the cutting torch, will probably be cut with the —

(*a*) Slitting shear.

(*b*) Throatless shear.

(*c*) Doall.

(*d*) Marvel band saw.

19. A heavy cast iron tool used to bend pipe and strap iron is called a —

(*a*) Universal Iron Worker.

(*b*) Power slip-forming roll.

(*c*) Bending slab.

(*d*) Power pipe bender.

20. A tool which may be attached to a drill press for cutting medium sized circles in sheet metal is called a —

(*a*) Circular saw.

(*b*) Shaper.

(*c*) Turret punch.

(*d*) Hole saw.

21. A useful machine tool upon which slitting, shearing, notching, and coping may be done and upon which work can be done at both ends of the machine at the same time is called —

(*a*) Universal Iron Worker.

(*b*) Marvel metal cutting band saw.

(*c*) Doall.

(*d*) Power combination machine.

22. A machine which will punch various sized holes up to $1\frac{1}{4}$ inches in diameter is called —

(*a*) Doall.

(*b*) Turret punch.

(*c*) Power combination machine.

(*d*) Universal Iron Worker.

23. A machine used to cut irregular curved edges but which has no guides to aid in the cutting is called a —

(*a*) Throatless shear.

(*b*) Universal Iron Worker.

(*c*) Marvel band saw.

(*d*) Power combination machine.

24. $\frac{1}{4}$-inch sheetmetal used to make cylindrical sections or tank bodies can be easily formed with a —

(*a*) Power combination machine.
(*b*) Universal Iron Worker.
(*c*) Bending slab.
(*d*) Slip-form roll.

25. The source of power from which several welders may work at the same time comes from a —

(*a*) 150 amp. motor generator set.
(*b*) Stationary motor generator set.
(*c*) System of storage batteries on a control panel.
(*d*) Series of transformers.

26. A machine upon which work can be fastened securely and tilted into various desired positions for welding is called a —

(*a*) Portable welding set.
(*b*) Tilt-top table.
(*c*) Welding positioner.
(*d*) Slab.

27. In addition to having material securely in place when using the power hacksaw, the work must be kept —

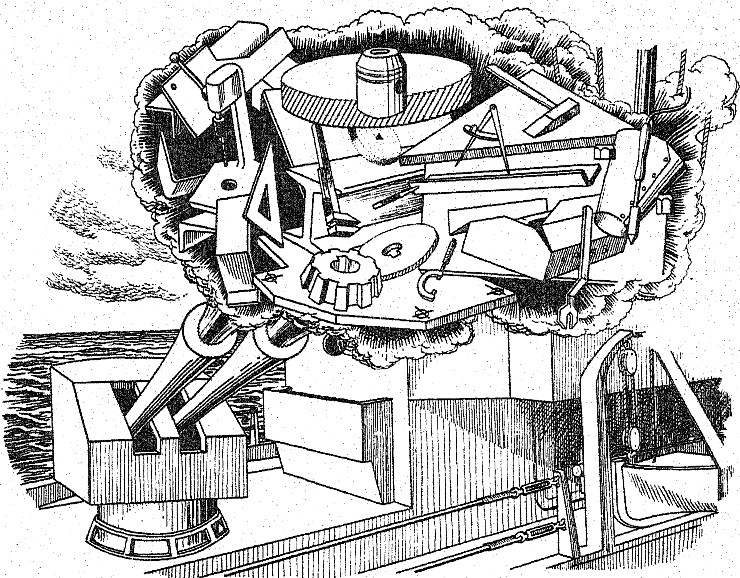
(*a*) Faired.
(*b*) Fayed.
(*c*) Lubricated.
(*d*) Calked.

28. Miter cuts can be best accomplished on heavy cylindrical sections by using a —

(*a*) Marvel metal cutting band saw.
(*b*) Doall.
(*c*) Power hacksaw.
(*d*) Universal Iron Worker.

29. The cutting of irregular curves on the inside of a blank can be best accomplished with a —

(*a*) Marvel metal cutting band saw.
(*b*) Power combination machine.
(*c*) Doall.
(*d*) Throatless shears.



CHAPTER 3

MATERIALS

In every war since the invention of gunpowder, the winning outfit has been the one that could throw the greatest amount of metal at the enemy in the shortest time. As a fighting man, you are interested in how wars are fought and won. As a Metalsmith, your greatest interest in metallic materials is not in throwing chunks of metal at any particular individual, but in selecting and shaping the materials into desired forms. You will be using the same basic materials in your work of construction and repair as the gunner uses when the big guns are fired, or that are in the block-busters dropped on enemy installations. Perhaps, at first glance, a smith or a worker in metals is not as important as the man who drops the "eggs." But remember that those eggs could not be dropped unless the planes, guns, and ships were first built and then maintained in A-1 condition.

The metallic materials with which you will work are divided

into two general classifications: FERROUS AND NONFERROUS. A ferrous metal is composed mostly of iron. Pig iron, cast iron, ingot iron, wrought iron, carbon steel, and the various alloy steels (structural as well as tool steel) are ferrous metals. All other metals are nonferrous. You are probably familiar with many nonferrous metals such as gold, silver, lead, zinc, aluminum, copper, and tin. These metals and combinations of them in such useful alloys as solder, brass, and bronze are used in large amounts in the construction and maintenance of your ship. Look around your destroyer or battleship. Pipes, cables, ladders, pots, pans, and machinery are all made of metallic materials. The greatest tonnage of any one metal used in the construction of your ship is steel. Look at the deck you are standing on. Maybe it's covered with teakwood planks. But under that planking are steel plates, supported by structural shapes such as **I**-beams, **T**-bars, or angle bars. Have you ever given any thought to the manner in which these plates, fittings and shapes were manufactured? A lot was done to them before they went into the structure of the ship, or reached your supply room.

FERROUS METALS

Before iron and steel products can be manufactured, iron ore must be mined. Red hematite is the most common commercial iron ore. Once the ore is mined, it is converted to metallic iron by being melted in a blast furnace in the presence of coke and limestone. The chemical and physical reaction which takes place in this process reduces the ore to molten iron. This molten iron is drawn from the bottom of the furnace and poured into sand molds to form shapes of convenient size, known as "pigs."

Pig iron is composed of about 93 percent iron, 3 to 5 percent carbon, and varying amounts of other elements. Pigs are used in the manufacture of cast iron which, because of its brittleness and low tensile strength, is limited to use in such parts as motor mounts, gears, and housings. When pig iron is further refined in a puddling furnace, still more of its impurities are removed. The product of this puddling process is WROUGHT IRON.

Ingot iron may not be in your stock pile. It is a commercially pure iron—99.9 percent pure. This iron is manufactured by the open-hearth method. The chemical analysis, structure, and properties of this iron and of lowest carbon steel are practically the same. The difference is this: In ingot iron the carbon content is considered an impurity. Any element is considered an impurity when it has an undesirable or unwanted effect on the product. In steel the carbon content is considered an alloying element. An alloying element produces a desired or wanted effect. The lowest carbon content steel—"dead soft"—has about 0.06 percent higher carbon content than ingot iron.

Wrought iron and ingot iron are obtainable in sheets and bars. You may use them in the construction of lockers and ventilation ducts. Wrought iron is also used in the manufacture of boiler tubes, piping, rivets, and nails.

Steel is manufactured from pig iron by decreasing the amount of carbon and other impurities present in the pig. About 15 pounds of manganese are added to every ton of pig in this stage of the manufacture of steel. Manganese carries off sulphur and oxygen which, if left in the product, would cause the steel ingots to crack when they reach the rolling mills.

You'll hear reference made to Bessemer steel, open-hearth steel, and crucible steel. These terms refer to methods of manufacture. The method of manufacture is one way by which steel is classified. Another method of classifying steel is by the elements other than iron and carbon that are present in it. All steels are alloys of iron and carbon. It is during the molten stage in the metal's manufacture that controlled amounts of alloying elements are added to make a steel of the desired composition.

When the process of purifying and alloying steel is complete, the metal is drawn off and poured into ingot molds. It is then permitted to solidify and, in some cases, it is sent directly to the shaping mills. There it is formed into billets, plates, and structural shapes.

The chemical analysis of wrought iron and of mild steel are practically the same; that is, the elements of both metals are very similar. The difference in the properties of the two stocks

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is caused by a difference in the process of manufacturing them.

Wrought iron is made by a process of puddling, squeezing, and rolling. This process introduces slag into the iron and gives it a fibrous internal structure which is responsible for its workability and for its resistance to corrosion.

Steel is made by a process of smelting, decarburizing, deoxidizing, solidifying, and rolling. The decarburizing takes out the excess carbon, and deoxidizing removes other impurities by the use of manganese. During most of its manufacture, steel is in a molten condition. When it is poured into ingot molds, it solidifies into a granular structure. It is then sent to the rolling mills to be formed into shape.

The difference between wrought iron and steel, then, is that wrought iron has a fibrous internal structure similar to that of a piece of wood, while the internal structure of steel is similar to the internal granular structure of a frozen sherbet. But on the surface, a sheet of black wrought iron or ingot iron looks the same as a sheet of black steel.

You won't have any difficulty in fabricating or joining mild steel, and you'll find that ingot iron and wrought iron can be fabricated and joined even more easily. The unprotected surface of a wrought iron sheet will stand up against weather conditions longer than mild steel. Wrought iron is more expensive than steel, and you may not have it in your stockpile.

You'll have a number of different types of steel aboard your ship or station. Most of this steel will be in the form of structural shapes, sheets, plates, and bars. The most important types of structural steel are: MILD STEEL, MEDIUM STEEL, HIGH TENSILE STEEL, SPECIAL TREATED STEEL, and STAINLESS STEEL.

Mild steel (0.05 percent to 0.30 percent carbon content) is used when structural strength is of no great importance, and when a great deal of flanging, shaping, and other shop operations are involved.

Medium steel (0.30 percent to 0.60 percent carbon content) is similar to mild steel in its workability. But it is harder and stronger than mild steel and is used when structural strength is required. You will find this steel used in decks, shell plating, main bulkheads, frames, and in many forgings.

High tensile steel (HTS) is used in various parts of a ship where material of greater strength is required. This steel contains small additions of various alloying elements that give the steel extra hardness and toughness. An example of this steel is Armco high tensile steel which is made up of 0.12 percent carbon, 0.20 percent manganese, 0.10 percent silicon, 0.35 percent copper, 0.50 percent nickel, 0.05 percent molybdenum, and 0.05 to 0.15 percent phosphorus. You won't have any great difficulty fabricating with HTS. It's just a little tougher to work. It's not a good idea to punch large-sized holes in HTS, because you may break the punch. When you need to make holes, use a cutting torch.

Special treated steel (STS) is designed to protect the vital parts of your man-of-war. Protective decks, conning towers of submarines, and many other vital parts are protected by this type of steel. You won't be able to punch or shear this steel. A small percentage of chrome-nickel has been added, and the steel has been specially treated to obtain hardness and toughness. All of your cuts will have to be made with a cutting torch. This will include any holes needed for riveting. When you have to do welding on STS, you'll have to use a special rod that contains 25 percent chromium and 20 percent nickel. You'll see and use another kind of steel aboard your ship. If it is bright and shiny, the metal might easily be stainless steel.

Stainless steel is commonly referred to as CRS. Don't get this mixed up with monel, which is a nonferrous metal. This steel is used in locations where resistance to corrosion is important. You'll see this steel used around the sick bay and galley a great deal. Other uses are on air-ports, ladders, hatches, and for decorative purposes. This metal is easily worked in the shop. It must be welded with a welding rod of the same composition as the base metal. You won't be able to flame-cut this steel because instead of burning out as regular steels do it will merely melt. The most common stainless steels are 25-20 (25 percent chromium and 20 percent nickel) and 18-8.

Steels are designed and manufactured for a wide variety of purposes and applications. In addition to structural steels, you will have bars of HIGH CARBON STEEL (more than 0.60 per-

cent carbon) and bars of HIGH SPEED ALLOY TOOL STEEL. Many of your hand and machine tools will be made from these. You will make forgings from some of these metals at one time or another, and you'll have to heat-treat the forgings.

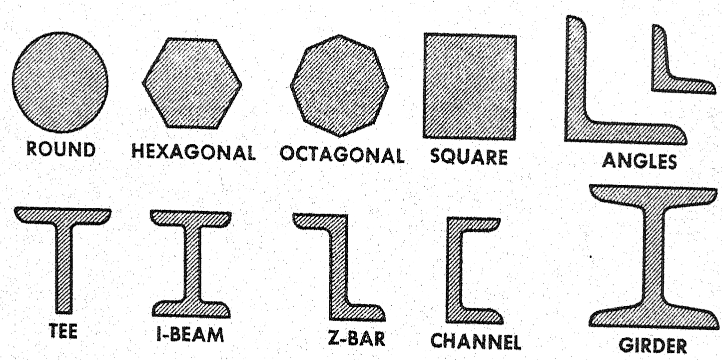


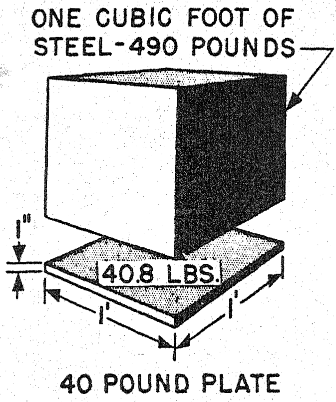
Figure 31.—Rolled shapes.

If your duty station is on a large ship, your storeroom will have all of these steels in various sizes of square, round, and flat bars, sheets of different sizes and weights, rivets and machine screws of all sizes and descriptions, and various hardware articles.

Some steels are tailor-made to specifications for a particular job, or for a desired physical property. Some of these properties may be ease-of-cutting, extra strength, toughness, or workability.

In the *plain carbon steels,* which are true alloys of iron and carbon, the amount of carbon in the steel determines the property of the steel. It also determines the hardness of the steel as well as its ability to respond to heat-treatment. Although carbon steels are true alloys, you'll seldom hear them referred to as alloys.

Alloy steels have elements other than carbon added to develop certain desired properties. Among the more common alloying



STEEL PLATE

THICKNESS	NAME
2"	80 POUND
$1\frac{1}{2}$"	60 POUND
1"	40 POUND
$\frac{3}{4}$"	30 POUND
$\frac{1}{2}$"	20 POUND
$\frac{3}{8}$"	15 POUND
$\frac{1}{4}$"	10 POUND
$\frac{1}{8}$"	5 POUND
$\frac{1}{16}$"	$2\frac{1}{2}$ POUND
BELOW $\frac{1}{16}$"	SHEET

Figure 32.—Thickness and weight of steel plate.

ingredients are nickel, chromium, vanadium, silicon, and tungsten. One or more of these alloying ingredients may be added to the steel during its manufacture.

Nickel steels usually contain from 3 to 5 percent nickel. Nickel steels have increased strength, better corrosion resistance, and greater toughness or ruggedness.

Chromium steels resist wear. For this reason ball bearings are often made of an alloy containing about 1 percent chromium and 1 percent carbon.

Chrome-vanadium gives a maximum of strength with a minimum of weight. Take a look at a good set of 12-point box-end wrenches. You'll see "chrome-vanadium" stamped on the handles. Steels of this kind contain 0.15 to 0.25 percent vanadium, 0.60 to 1.50 percent chromium, and 0.10 to 0.60 percent carbon, and they are used mainly where super-strength is desired. You'll find them used for crankshafts, gears, and axles.

Tungsten steel is said to be "red-hard." You will hear about a steel having the property of "red-hardness" before you have been around metal workers any length of time. Red-hardness is the ability of a steel to remain hard enough to continue cutting even after it becomes red hot. Tungsten steel is a special alloy.

A good grade of this high-speed steel contains 13 to 19 percent tungsten, 1 to 2 per cent vanadium, 3 to 5 percent chromium, and 0.60 to 0.80 percent carbon. This alloy is expensive to produce and its use is mostly restricted to the manufacture of cutting tools, such as drills, lathe tools, and milling cutters.

Molybdenum is often used as an alloying agent for steel in combination with chromium and nickel. The "moly" adds toughness to the steel. It's used instead of tungsten to make cheaper grades of high-speed steel.

Here are some of the symbols for the various elements used in alloy steels:

Iron (Fe)	Nickel (Ni)
Carbon (C)	Chromium (Cr)
Phosphorus (P)	Vanadium (V)
Sulphur (S)	Silicon (Si)
Manganese (Mn)	Tungsten (W)
Copper (Cu)	Molybdenum (Mo)

You'll see these symbols used when you check through technical handbooks and Navy specification manuals. You should learn these symbols as they are a part of the vocabulary of the language of metals—your language.

Steels are manufactured according to rigid specifications. These specifications are numbered by one system or another. If you know the number of the steel, you can identify the class to which it belongs. An example of the numerical system of identification is that used by The *Society of Automotive Engineers* (S.A.E.)

The S.A.E. number system utilizes a four digit number. A *1008* S.A.E. steel is plain carbon steel. The first digit, *1*, indicates that it is a carbon steel. The second digit, *0*, tells you that there is no other alloying element. The last two digits, *08*, tell you the approximate percentage of carbon present—in this case, .08 percent. Other steels are indicated by the following first digits: *2*—nickel steel; *3*—nickel chromium steel; *4*—molybdenum steel; *5*—chromium steel; *6*—chromium vanadium steel; *7*—tungsten steel; *8*—National Emergency steel (substitute steel developed during World War II); and *9*—silicon-manganese.

The second digit usually indicates the main alloying element, and the last two digits indicate the approximate carbon content of the steel. The S.A.E. number *2340* indicates a nickel steel of approximately 3 percent nickel and .40 percent carbon.

There are a number of other systems used to identify and set forth the specifications of steel. You may have occasion to use Navy and Federal specifications for steel and other materials. For example, the Navy symbol for a certain molybdenum steel used for high-pressure tubing is *44T33* You can check the supply office of your ship or station when you need information about numerical systems.

NONFERROUS METALS

One of the most important nonferrous metals used in the construction of your ship is COPPER. A battleship requires about 1,000 tons of this material in the form of wire, sheet, plate, and in copper alloys, such as brass and bronze. Like iron and all other base metals, ore bearing metallic copper must be mined, smelted, refined, and then rolled to the desired shape.

In comparison with iron, copper is a rare metal. Ores which bear iron usually contain 50 percent metallic iron, while the best copper ores contain only 5 percent metallic copper. This means that a great deal more copper ore than iron ore must be mined to get the same tonnage of both metals. The process of extracting the metal from copper ore is much longer than for iron ore. The copper ore must first go to crushers where the gangue or worthless rock is partially removed. After this crushing process, the ore, bearing 20 to 25 percent metallic copper, is roasted to reduce the sulphur content. The mass then goes to a converter similar to the Bessemer furnace used in the manufacture of steel. The pig copper obtained after this step is sometimes called blister copper because of its blistered appearance. The remaining impurities are removed in a refining furnace. The final product is a copper that is 99.95 percent pure.

Copper sheet, pipe, and tubing have a reddish brown color, are easy to work, and have many applications. You'll use them to

make ball floats, containers, and soldering irons. You'll see sheets and rods that have a protective coating of copper. Don't be alarmed if these surfaces are covered with a green tarnish. This tarnish is called verdigris and has no material effect on the copper. You have probably brushed or polished plenty of this tarnish or corrosion from the metal when you shined bright work as a boot.

Copper is an excellent conductor of electricity and it has excellent resistance to salt-water corrosion. Its manufacture is costly in comparison with that of steel. This is one of the chief reasons why other metals are substituted for it whenever possible.

Copper becomes hard when worked, but is easily softened by heating it to a cherry-red color and then cooling it. Annealing and softening are the only heat-treating procedures applied to copper.

You'll join copper seams with rivets, silver solder, bronze brazing rod, and soft solder. You can also use standard sheet metal seams as well as gas and arc welding procedures.

Zinc, as you will most often see it, will be in the form of a protective coating on sheet metal. These sheets are called galvanized sheets. The process by which the protective coating is applied to the iron or steel is known as galvanizing. The zinc coating has a bluish-white spangled appearance.

The greatest use of zinc is as an alloying ingredient in making brass and some bronze. Pure zinc sheets, called zinc protectors are used to protect the hull and hull fittings from galvanic action. These zinc protectors are installed on the hull of all steel ships. You'll also use zinc to cut or weaken raw acid for use as a soldering flux.

Galvanic action is set up when unlike metals are in close contact with each other and immersed in salt water. An electric current is generated between the unlike metals, causing corrosion or pitting of the metal from which the current flows. When zinc protectors are installed, the current flows from the zinc, eating it away, and in this manner prevents corrosion of the steel hull and the bronze bearings, shafts, and propellers. For a more detailed discussion of galvanic action and zinc pro-

tectors see *Bureau Ships Manual*, chapter 12, p. 6, and chapter 46, p. 45.

Lead will probably be the heaviest metal that you'll have to work. When you go down to the storeroom to drag out a sheet of lead, you'll have a load on your shoulders. Lead weighs about 700 pounds a cubic foot. It is available in pig and sheet form. The sheets will be rolled up on a rod like a carpet, and you'll unroll and cut off as much as you need to use. You'll see sheet lead used to line sinks or protect bench tops where a great deal of acid is used. Very likely you'll have a container made of sheet lead in which you will cut or dilute your hydrochloric and muriatic acid with zinc.

The surface of lead is grayish in color, but when it is scratched or scraped, it becomes very white. Because of its softness, a lead block is often used as a backing material when punching holes with a hollow punch, or for bumping or hammering sheet metal forms.

Your most frequent use of lead will be in one of its alloyed forms. When lead is alloyed with tin in various proportions to form soft solders, you have one of the most commonly used alloys of nonferrous metals. You have had some experience with the many applications of soldering. Chapter 6 discusses solders and soldering in detail.

Tin is seldom used except as an alloying ingredient. But in this capacity it has many important uses. Alloyed with lead, it makes a soft solder. When alloyed with copper, it produces bronze. Lead and tin both resist corrosion very well, but tin has the added advantage of being nonpoisonous. For this reason, many food containers are fabricated from sheet material which has been coated with tin.

True brass is an alloy of copper and zinc. Complex brasses are those containing additional alloying agents, such as aluminum, lead, iron, manganese, or phosphorus. Naval rolled brass is about 60 percent copper and 40 percent zinc, and is practically free of impurities. It can resist corrosion.

Brass sheets and strips are available in soft, ¼-hard, ½-hard, full-hard, and spring grades. The hardness is accomplished by cold rolling. All grades of brass can be made softer by annealing

at a temperature of 550° to 600° F. The brass should be allowed to cool by itself without quenching. Don't overheat it or you may burn out the zinc in the brass.

Bronze made of 84 percent copper and 16 percent tin was the best available metal before steel-making techniques were discovered. A thousand years ago bronze tools and weapons were the best to be had. And the first good naval cannon was made of bronze some five hundred years ago.

KIND OF BRASS	PERCENT OF ALLOY ELEMENTS			
	Copper	Zinc	Tin	Lead
Naval rolled	60–61	38–39	1.0	0.05
Commercial rolled	60–70	30–40	Some	Impurities
Cartridge or Spinning	65–73	27–35	....	....
Yellow (Cast)	62–73	25–35	....	2.0–3.0
Med. red (Cast)	72–87	8–15	2.0–3.0	7.0–10
Composition F (Cast)	85	15.0	....	....
Red (Cast)	85	5.0	5.0	5.0
Muntz metal	54–60	40–46	....	....

Figure 33.— Content of brass alloys.

Although bronze was originally an alloy of copper and tin, many complex bronze alloys containing three or more elements have been developed. Therefore, there is now no distinct line between brass and bronze. In fact, commercial bronze (used for hinges and other hardware) is really a low brass containing 90 to 95 percent copper and 5 to 10 percent zinc.

Most of the work that you will do on brass and bronze will be in the nature of repair. You'll build up and repair brass or bronze gears and castings by brazing and welding.

An application of sheet brass is found in the kick plates you may have polished around the ship. You'll also have sheet, strip, and wire-spring bronze from which you'll make numerous small springs.

Copper-nickel alloy has come into its own in recent years. The Navy now uses it extensively to convey salt water because it is highly resistant to electrolysis or galvanic action. In sheet form, you may use it to construct small storage tanks and hot-water reservoirs. Copper-nickel alloy contains 70 percent

KIND OF BRONZE	PERCENT OF ALLOYING ELEMENTS			
	Copper	Zinc	Tin	Lead
Commercial.	90–95	5–10	. .	. .
Bearing.	80	. . . .	10	10
Tobin.	60	38	2	. .
Phosphor.	87	2.3	10	.7% Phos.
Aluminum.	95	5% Aluminum		
Silicon.	95	3% Silicon, 2% other elements		

Figure 34.—Kinds of bronze.

copper and 30 percent nickel. This alloy must be worked cold, although it has the general working characteristics of copper. Copper nickel is best joined by the silver-soldering process.

Monel contains from 65 to 68 percent nickel, about 30 percent copper, and small percentages of iron, manganese, and cobalt. In appearance monel resembles stainless steel. In fact, it has many of the same qualities as stainless steel.

Monel is harder and stronger than either nickel or copper. It also has good ductility—that is, it can be easily worked. Monel has a very high resistance to corrosion, and is so strong it may be substituted for steel where corrosion resistance is of primary importance. These excellent qualities make it valuable for use in pump parts, turbine blades, table tops, laundry equipment, steam valves, containers, and head fixtures and equipment. Nuts, bolts, screws, control parts, and other fittings are also made of monel.

Monel can be worked cold. It also can be forged and welded. Don't work monel between 1200° and 1600° F. It becomes "hot short" or brittle when worked in this temperature range.

K-monel is a special improved type of alloy that is stronger and harder than ordinary monel. Its strength is comparable to that of heat-treated steels. K-monel is used for instrument parts that must resist corrosion.

Inconel is a high-nickel alloy containing 78½ percent nickel, 14 percent chromium, 6½ percent iron, and about 1 percent of other elements. It has great resistance to corrosion and retains its strength at high temperatures. Exhaust systems of engines are often made of inconel.

Aluminum is being used more and more in ship construction because of its light weight, easy workability, good appearance, and other desirable properties. Pure aluminum is soft and is seldom used in its unalloyed form because it is not hard or strong enough for structural purposes. Aluminum is improved by the addition of other elements to form aluminum alloys.

Aluminum alloys usually contain 90 percent aluminum or more. When elements such as silicon, magnesium, copper, nickel, and manganese are added, an alloy stronger than mild steel is produced. Pure aluminum, however, is only about one-fourth as strong as steel.

Duralumin was the name given to one of the first strong structural aluminum alloys. There are now so many different alloys that they are designated by numbers—*2*, *3*, *4*, *17*, *24*, *52*, etc. These numbers indicate the contents of aluminum alloy. Letter symbols are used to indicate the method of manufacture and the cold-worked or heat-treated condition of the metal.

Wrought alloys—those used for rolling, pressing, and hammering—are indicated by an *S*. Casting alloys are indicated by a *B*. Pure aluminum is classified as *2S*. The alloy formerly called duralumin is now classified as *17S-T*. The *T* means the metal is heat-treated.

Wrought aluminum alloys that cannot be heat-treated, such as *3S*, *4S*, and *52S*, may be hardened by cold-working. The following markings (used here with *3S* alloy) are used to indicate the hardness of non-heat-treatable alloys:

SYMBOL	CONDITION
3S-O	Dead soft (annealed).
3S-¼H ...	One-quarter hard.
3S-½H ...	One-half hard.
3S-¾H ...	Three-quarters hard.
3S-H	Hard.

There are many aluminum alloys. You may use some of them in sheet form to make and repair lockers, shelves, furniture, boxes, trays, and other containers. Sheet stock is usually labeled with its proper symbol and with its thickness in thousandths of an inch.

Sheet aluminum alloy used for new naval construction is

usually specified as *52S* (*Navy Specification 47A11*) for sheets up to .102 inch thick, and *53S12* (*Navy Specification 47A12*) for thicker sheets and plates. The content of these two alloys is shown in the following table:

ALLOY	NAVY SPEC.	SILICON	MAGNESIUM	CHROMIUM
52S	47A11	....	2.5%	0.25%.
53S	47A12	0.7%	1.3%	0.25%.

The remaining 97 to 98 percent is aluminum and allowable impurities.

Bars, rods, shapes, and wire are made of *53S* stock (*Navy Specification 46A10*). Rivets made of *53S* stock are used with both *53S* and *52S* sheets and shapes. The rivet specification number is *43R5*, Grade E. These rivets should be used as received.

As a general rule, soldering aluminum is unsatisfactory, although it can be done when you have the proper solder and fluxes available. Aluminum and its alloys can be spot-welded, fusion-welded, or riveted.

Aluminum alloys should not be exposed to salt water or used in damp places. They should never be installed in close contact with steel or with copper alloys because an undesirable, corrosion-producing, electrical current is set up. Suitable insulating materials—fiber, rubber, or composition—should be installed between dissimilar metals. The metals may be insulated by coating the contacting surfaces with zinc chromate paint.

Threaded parts made of aluminum alloys should fit loosely, and be coated with an "anti-seize", a compound that prevents "freezing" or sticking caused by corrosion.

Pure aluminum resists corrosion well, but aluminum alloys soon corrode unless properly protected. The content of the alloying agents determines, to some extent, the rate of corrosion. Zinc chromate is one of the best protective coatings for aluminum surfaces.

Many motor boat canopies—for example, the captain's "gig"—are made of aluminum. Sometimes these canopies

accidentally get damaged. You may have to do some aluminum welding as well as straightening on that job. Another aluminum repair job may be that of repairing aluminum chairs. The Navy uses a lot of this lightweight material, and when it is damaged, you'll be the man who does the fixing.

USE WHAT YOU HAVE

Before you can make use of the ferrous materials that you will have in your storeroom, you will have to plan the job. As a striker and, usually, as a Third Class Metalsmith, you won't have to do much of your own planning. But as you become more proficient in your rate, some of this planning will be left up to you. You will have plans and blueprints to work from in many cases. Review your basic training course, *Use of Blueprints*, NavPers 10621.

Select the stock for the job. This selection will be determined by the job at hand. In chapter 10 you will learn the basic layout procedures you will use to form the desired shapes. The layout for plate sections will be the same as with sheet metal. However, you must bear in mind one important point: When you are working with very thin sections of sheet metal, you won't have to worry about BEND ALLOWANCE. On the heavier sheets (ferrous or nonferrous) or on plates you'll have to keep this factor in mind and make allowances for the thickness of the metal. Figure 35 illustrates the manner in which a thick piece of metal bends. The inner section compresses and the outer radius stretches. You will notice that the portion in the center of the sheet neither compresses nor stretches. This is known as the NEUTRAL AXIS. You will use this neutral axis when making layouts and allowances for bends. Consider it as a paper-thin sheet of metal. As you can see in the illustration, the neutral axis is at the center or one-half the thickness of the sheet. You will allow for the thickness of metal on each side of the axis and make your layout accordingly.

After making your layout according to plan, cutting it to shape, and forming the bends and curved sections, you'll join the seams. Most of your plate work will be joined by welded

seams, but you may have to use riveted seams in some plate sections.

Good riveting can be done, if necessary, with no other tools than a ball peen hammer and a sledge for backing the rivet. You may or may not need some means for heating the rivets, but you will need tongs for handling them if heating is required.

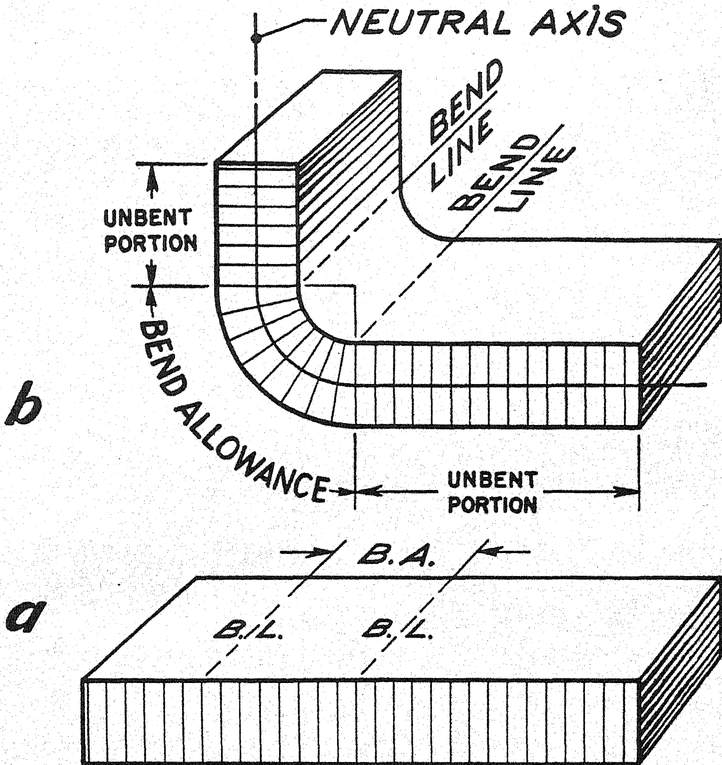


Figure 35.—Neutral axis and bend allowance.

In general, the rivet you'll use to join the different structural members, should be of the same material as the metals being joined—mild steel rivets for mild steel, and high-tensile rivets for high-tensile plates. Rivets can be made of almost any con-

struction material. You may have wrought-iron, steel, copper, aluminum, or various alloy rivets. All are available in different-sized diameters, different lengths of shank, and a number of types of heads. Figure 36 illustrates types of rivet heads and the types of points that are formed in riveted construction. For the most part, you will not be concerned with an entire heavy-plated rivet construction, as most of your repair work be done by welding. But you may have to burn out bad rivets and replace them.

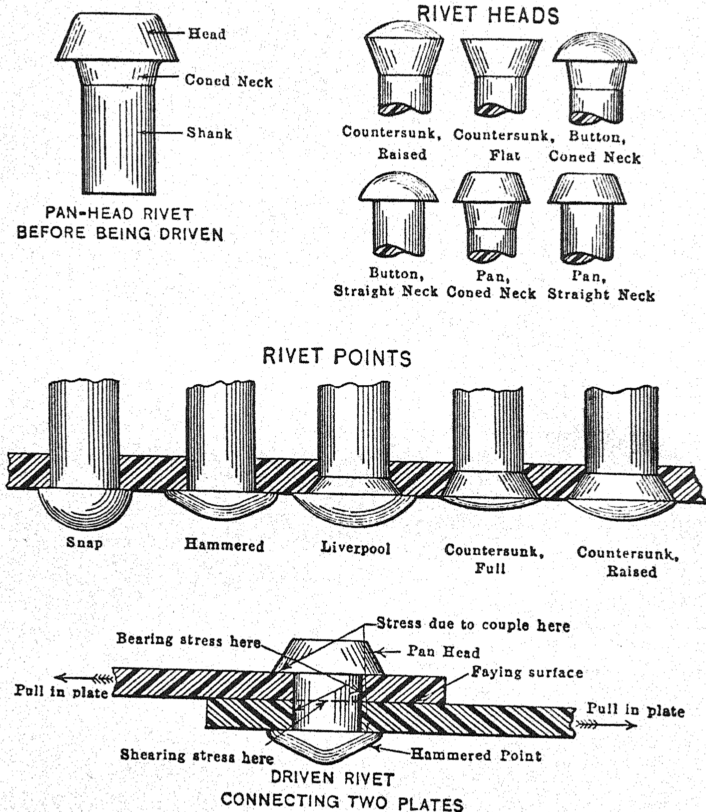


Figure 36.— Types of rivets.

Here are some practical suggestions for riveting:

1. The FAYING SURFACE—the surface between the two riveted plates or shapes—must be carefully cleaned and given a protective coating of paint before the plates are riveted together.
2. The rivet holes must be FAIR—lined up. Unfair holes must be faired either by lining up with a drift pin or reaming with a tapered reamer. When a hole has to be reamed to be faired up, a larger-sized rivet must be used. A hole that has been reamed is a size larger than that specified for a particular size of rivet and wouldn't have the designed strength.
3. Prior to riveting, sections of plates to be riveted are closely bolted together. Enough bolts should be used to insure close contact of the faying surfaces. After rivets are driven in the free holes, the bolts are removed and are replaced by rivets.
4. Large rivets must be heated. You'll have to exert care not to overheat the rivet because a burned rivet is useless. A properly heated rivet should be a light red when taken from the fire, and cherry red when driven. Rivets under $\frac{3}{8}$-inch in diameter may be driven cold.
5. When a rivet is inserted in a hole, don't drive the point until you lay the head up solidly against the plate with a few blows of a hammer.
6. Form the point on the rivet by striking a series of blows around the edge of the rivet. Figure 37 illustrates a rivet properly set up for driving. The dolly bar in the lower half of the figure is a tool that is used for bucking (backing up) the rivet. For removing rivets the cutting torch is your best tool. (See chapter 9 for detailed instructions.)

Calking is the metal-working process you'll use to make riveted joints and rivets water-tight and oil-tight. Metal calking is the process of making joints tight by forcing the edges of one plate or member hard against another edge or members. Calking may injure a joint instead of helping it if it carelessly or improperly done.

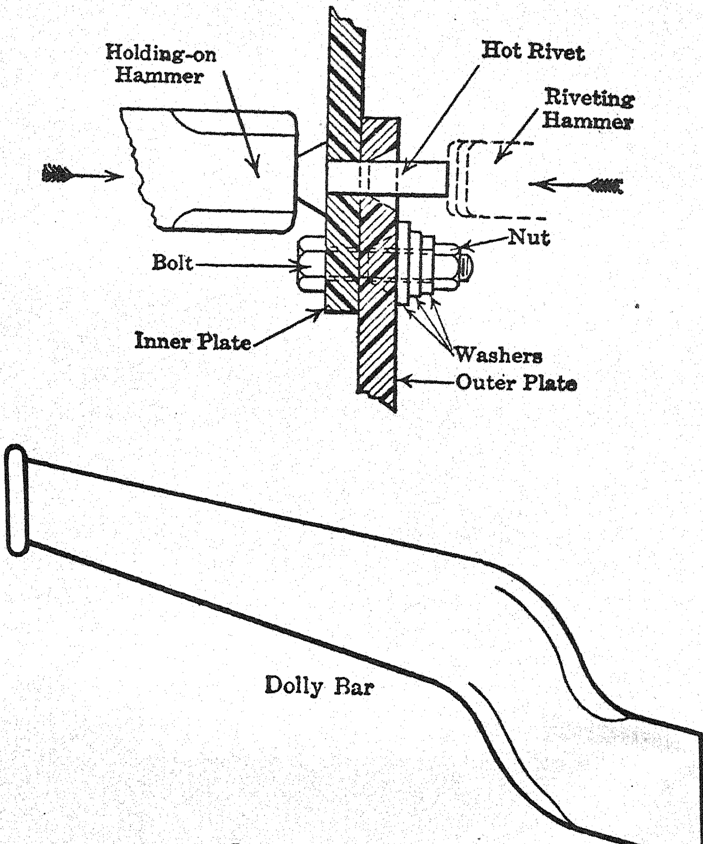


Figure 37.— Driving a rivet.

The calking process is accomplished in two distinct steps:

1. Forming a groove or furrow with the splitting tool (see figure 38). This groove should be about $\frac{1}{16}$-inch deep and $\frac{1}{8}$- to $\frac{3}{16}$-inch wide, depending upon the thickness of the plate.
2. Tamping the joint with the calking tool as illustrated in figure 38.

The distance from the edge of a plate to the nearest row of rivets should not be more than about two rivet-diameters, or

there will be insufficient pressure on the calking edge of the plate to maintain satisfactory tightness. Remember to calk from the inside of a tank or the side upon which the pressure will be exerted.

Poor calking is due to improper holding of the calking tool.

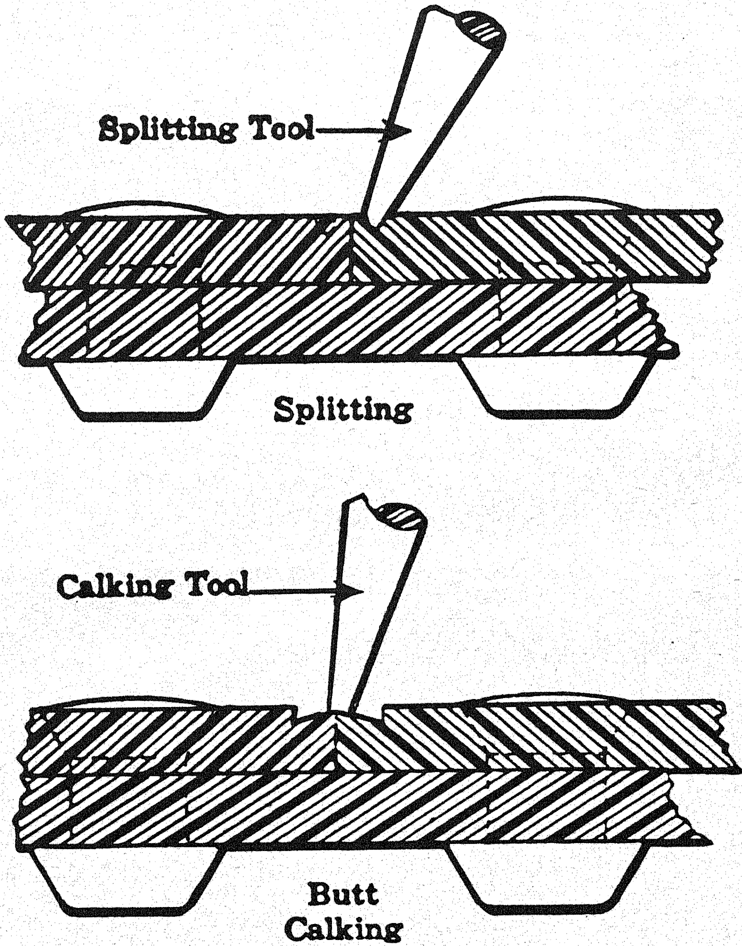


Figure 38.— Calking a butt joint.

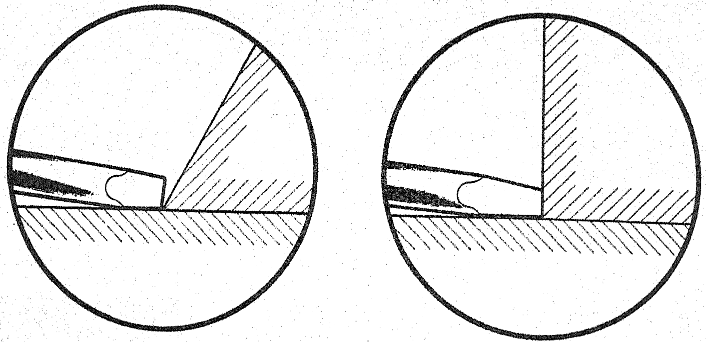


Figure 39.—Calking tools correctly held.

Figure 39 illustrates the correct way to hold the calking tool.

You will not be able to do satisfactory calking jobs on plates $\frac{3}{16}$-inch or less in thickness. Sections that must be made watertight on metal of this thickness are usually calked with a packing material.

You'll hear your shipmates talking about SOFT PATCHES. A soft patch is a metal sheet, cut to a desired shape. It is fastened in place with tap bolts or tap rivets, and is made watertight by use of a stopwater, such as white lead putty or painted canvas, between the plates of the joint. A soft patch is not calked. Soft patches are placed over a hole, a break, or over the thin section of another plate.

Pipe fittings are materials with which you will need to be familiar. Piping systems will usually be installed, maintained, and repaired by the Pipe Fitter on your ship or station. As a Metalsmith, you will use many pipe fittings, such as elbows, tees, unions, and crosses, in the fabrication of hand rails and life lines. When you fabricate these life lines and handrails, you may use screw fittings as illustrated in figure 41, or chamfered (beveled) fittings for welded joints. The only difference between these fittings is that one has internal threads cut to receive external threads on a pipe, while the other is manufactured to fabricate by welding.

You'll see a lot of different kinds of pipe and tubing aboard your ship. These pipes and tubes are used to transfer fuel,

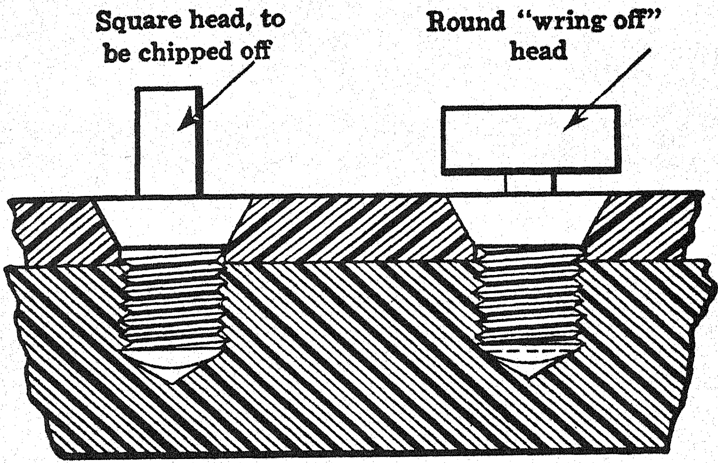


Figure 40.—Tap rivets.

steam, and fresh and salt water under various pressures. Because of the different liquids and pressures that they carry, pipe and tubing are manufactured from various metals and alloys in a number of wall thicknesses.

Pipe is generally designated by standard "iron pipe size" (I.P.S.), which is the nominal inside diameter. Pipe is primarily intended for fabrication by threaded joints.

Tubing, on the other hand, is primarily intended to be fabricated by welding, brazing, or silver soldering. You'll probably see tubing that has a greater wall thickness than some of the extra-strong or double extra-strong piping that you have aboard. Some of the tubing you'll see will have very thin walls like the copper-nickel tubing used for salt water lines, while the tubing used for high-pressure boilers has very thick walls. It is manufactured from a carbon-molybdenum alloy. When you are identifying pipe and tubing, remember that often there is no apparent visual difference between them. The only way to determine whether it is pipe or tubing is by the system under which it is intended to be fabricated.

The following table of symbols and weights of some of the better-known base metals and alloys is a handy reference. You

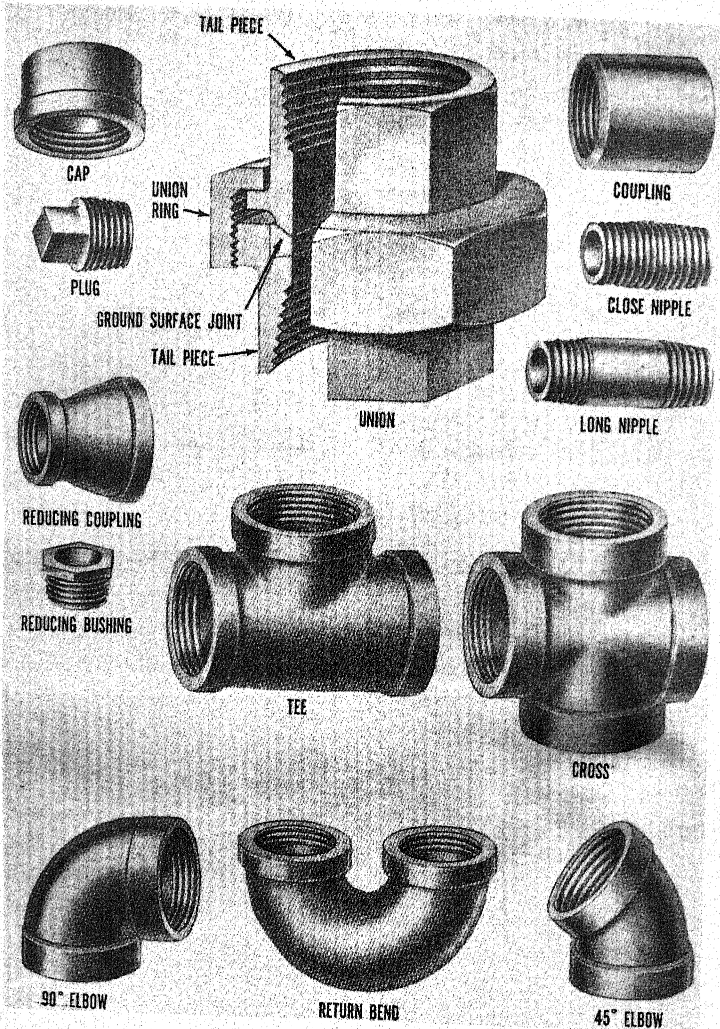


Figure 41.—Standard pipe fittings.

don't have to memorize all the symbols. But if you are going to be a Metalsmith, you are going to have to learn to talk the Metalsmith's language, and symbols are a part of that language.

Metal	Symbol	Weight Per Cu. Ft.
Aluminum	Al	164
Antimony	Sb	555
Beryllium	Be	113
Cadmium	Cd	540
Cobalt	Co	533
Chromium	Cr	436
Copper	Cu	555
Iron	Fe	480
Lead	Pb	710
Magnesium	Mg	109
Molybdenum	Mo	636
Nickel	Ni	556
Platinum	Pt	1344
Silver	Ag	655
Silicon	Si	150
Steel		490
Tin	Sn	455
Tungsten	W	1078
Vanadium	V	354
Zinc	Zn	437
Copper-Nickel (Cu 60%—Ni 40%)		555
Cadmium-Tin alloy (Cd-Sn)		480
Brass (Cu 90%—Zn 10%)		536
Bronze (Tobin)		503
Sulphur	S	
Manganese	Mn	

QUIZ

Select the one best answer to each of the following statements.

1. The bars formed from the first molten iron coming from a furnace are known as—
   - (*a*) Ingot iron.
   - (*b*) Pig iron.
   - (*c*) Wrought iron.
   - (*d*) Mild steel.

2. An iron which is 99.9 percent pure is referred to as—
   (*a*) Pig iron.
   (*b*) Wrought iron.
   (*c*) Cast iron.
   (*d*) Ingot iron.

3. In ingot iron, carbon is considered—
   (*a*) An impurity.
   (*b*) A necessity.
   (*c*) An alloying element.
   (*d*) A solidifying factor.

4. In steel, carbon is—
   (*a*) Considered an impurity.
   (*b*) Essential for oxidizing.
   (*c*) Considered an alloying element.
   (*d*) Essential for the puddling process.

5. Manganese is added to pig iron during the steel manufacturing process to—
   (*a*) Prevent cracking when rolled.
   (*b*) Give it extra hardness.
   (*c*) Increase its brittleness.
   (*d*) Make it corrosion resistant.

6. The main difference between wrought iron and steel is the—
   (*a*) Color.
   (*b*) Surface appearance.
   (*c*) Internal structure.
   (*d*) Fabricating difficulties in working steel.

7. A structural steel used for flanging and shaping where structural strength is not important is—
   (*a*) STS.
   (*b*) HTS.
   (*c*) Medium.
   (*d*) Mild.

8. A steel providing the structural strength required in decks, shell plate, frames, etc., is—
   (*a*) Mild.
   (*b*) Medium.
   (*c*) HTS.
   (*d*) STS.

9. A steel which has strength enough for structural protective uses is—
   (*a*) STS.
   (*b*) HTS.
   (*c*) CRS.
   (*d*) Medium.

10. Holes in STS needed for rivets will be cut with a—
   (*a*) Drill press.
   (*b*) Pneumatic drill.
   (*c*) Cutting torch.
   (*d*) Heavy duty punch and sledge.

11. A steel used in locations where resistance to corrosion is important is—
   (*a*) Special treated.
   (*b*) Stainless.
   (*c*) High tensile.
   (*d*) Medium.

12. A steel which when cut with a torch merely melts is—
   (*a*) High speed.
   (*b*) Special treated.
   (*c*) High tensile.
   (*d*) Stainless.

13. Steel specifications are usually indicated by—
   (*a*) A color code.
   (*b*) Its weight.
   (*c*) A numbering system.
   (*d*) Its thickness.

14. In the S. A. E. steel specification number 3250 the first digit will indicate—
   (*a*) The percent of alloy.
   (*b*) The percent of carbon.
   (*c*) The percent of tensile strength.
   (*d*) The type of alloy.

15. The second digit in S. A. E. 3250 will indicate—
   (*a*) The type of alloy.
   (*b*) The percent of alloy.
   (*c*) The percent of carbon.
   (*d*) The percent of corrosion resistance.

16. The approximate percent of carbon content of S. A. E. 3250 steel is—
   (*a*) 0.32.
   (*b*) 0.50.
   (*c*) 3.0.
   (*d*) 5.0.

17. The steel which gives a maximum amount of strength for a minimum amount of weight is—
   (*a*) Chrome-vanadium.
   (*b*) Tungsten.
   (*c*) Nickel.
   (*d*) Carbon.

18. The steel which is most heat resistant among the following is—
   (a) High-carbon.
   (b) Nickel.
   (c) Tungsten.
   (d) Chrome-vanadium.

19. Layout of bend allowances should be made from the—
   (a) External bend radius.
   (b) Internal bend radius.
   (c) Central axis.
   (d) Neutral axis.

20. The surfaces which are given a protective coating of paint prior to riveting, are referred to as—
   (a) Water proofing surfaces.
   (b) Faying surfaces.
   (c) Fairing surfaces.
   (d) Calking surfaces.

21. If rivet holes are in line, they are said to be—
   (a) Faired.
   (b) Fayed.
   (c) Calked.
   (d) Sized.

22. A metal working process used on plates over $\frac{3}{16}$-inch thick to make riveted joints water and oiltight is—
   (a) Faying.
   (b) Fairing.
   (c) Calking.
   (d) Packing.

23. The size of iron pipe is given in terms of its nominal—
   (a) Composition.
   (b) Inside diameter.
   (c) Outside diameter.
   (d) All thickness.

24. Tubing used for salt water lines is usually composed of—
   (a) Tin and lead.
   (b) Aluminum, magnesium, and chromium.
   (c) Pure copper.
   (d) Copper and nickel.

25. An outstanding property of copper is its—
   (a) Ease of tempering by heat and chemical treatment.
   (b) Extreme hardness due to cold working.
   (c) Ability to be made soft by annealing.
   (d) Low heat conductivity.

26. Containers used for acids are usually lined with—
   (*a*) Lead.
   (*b*) Copper.
   (*c*) Zinc.
   (*d*) Steel.

27. Bronze is an alloy of copper and—
   (*a*) Brass.
   (*b*) Tin.
   (*c*) Zinc.
   (*d*) Magnesium.

28. Brass is an alloy of copper and—
   (*a*) Tin.
   (*b*) Magnesium.
   (*c*) Iron.
   (*d*) Zinc.

29. A nonferrous material which resembles and has many of the same qualities of stainless steel is—
   (*a*) Dural.
   (*b*) Molybdenum.
   (*c*) Monel.
   (*d*) Copper-nickel.

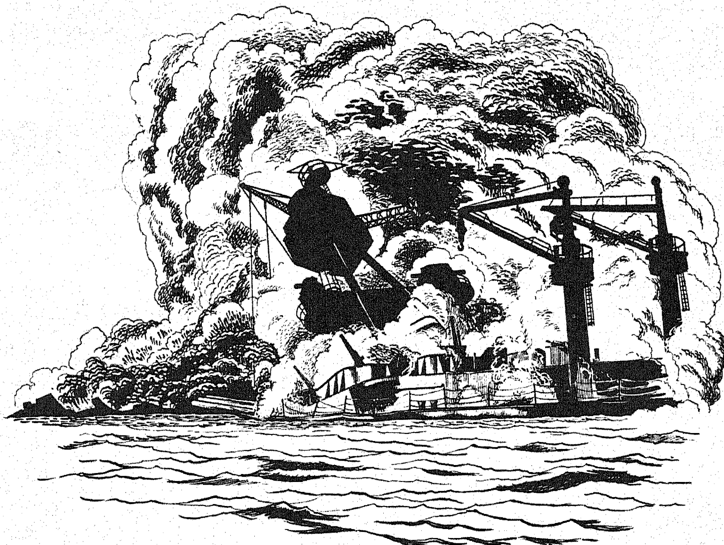
30. If an aluminum is represented by the number 17S-T, the 17 will indicate—
   (*a*) The alloy.
   (*b*) That it is wrought.
   (*c*) That it is heat-treated.
   (*d*) That it is annealed.

31. If an aluminum has been heat-treated, the identifying code will be—
   (*a*) S.
   (*b*) T.
   (*c*) H.
   (*d*) O.

32. The aluminum alloy used for rods, bars, shapes, and wire is designated as—
   (*a*) 2S.
   (*b*) 17S.
   (*c*) 24S.
   (*d*) 53S.

In list *A* are found the names of various metals and elements. Match items in column *A* with column *B*.

A	*B*
(*a*) Aluminum.	33. Zn.
(*b*) Brass.	34. Al.
(*c*) Bronze.	35. Cu.
(*d*) Cadmium.	36. W.
(*e*) Carbon.	37. Sn.
(*f*) Copper.	38. Fe.
(*g*) Iron.	39. Pb.
(*h*) Lead.	40. Si.
(*i*) Nickel.	41. Cd.
(*j*) Silicon.	42. C.
(*k*) Steel.	43. Ni.
(*l*) Tin.	
(*m*) Tungsten.	
(*n*) Zinc.	



CHAPTER 4

HEAT-TREATMENT OF METALS

Who will ever forget that Sunday morning of December 7, 1941! The Pacific Fleet was secure—or so we thought—lying at anchor in Pearl Harbor. In from the entrance to the bay came those planes, wearing the insignia of the Rising Sun. They kept coming—for an hour and 50 minutes. Down on battleship row we took it—not lying down, but we took it. Bombs, torpedoes, smoke, and flame. In less time than it takes to get a liberty pass, our fleet was broken, twisted, and burned. On the *Arizona*, broken and on the bottom, we had taken a bath of fire—not heat-treatment, but terrific heat. The foretop, once strong and sturdy, had crumpled under its own weight and had fallen forward. Heat had changed the properties of the metal, leaving it soft and pliable.

You've seen pictures of the twisted, warped metal of the wreckage. That's what concussion and heat can do. UNCON-

TROLLED heat can do a lot of damage. CONTROLLED heat can do a lot of good.

When we control the conditions of heating and cooling of a metal or alloy in its solid state, we are applying HEAT-TREATMENT. Certain structural changes take place within a metal when it is heated and cooled. By controlling the rate of heating and cooling (HEAT-TREATING), we can control these structural changes to develop the physical properties or characteristics that we want in the finished product.

The use to which we are to put a metal will determine the property it will require. We want a knife blade hard and capable of holding an edge. An anchor chain needs to be tough. The physical properties of metals, DUCTILITY, MACHINABILITY, TOUGHNESS, HARDNESS, and TENSILE STRENGTH, can be developed through heat-treating. Often you must sacrifice one property to gain another. For example, the harder you make a metal, the less ductile it will be.

The term DUCTILITY is used to describe that property of metal which makes it capable of being drawn, stamped, or hammered out thin. In other words—easy to work. Gold is such a metal.

MACHINABILITY is the term that is used to describe the ease with which stock is turned, planed, milled, or otherwise shaped in the machine shop. Proper heat-treatment improves this property and results in a finer finished appearance of the piece.

TOUGHNESS is that property of a metal which enables it to withstand shock, endure strains and stresses, and to be deformed without breaking.

The HARDNESS of a metal is that property which enables it to scratch and to resist scratching, cutting, denting, or wearing away. It may also be defined as the ability of a metal to resist penetration. You know, for example, that you can scratch a piece of lead with your pocket knife, and you know that you could not do the same to a piece of steel. Steel is harder than lead. It has properties which cause it to resist scratching and cutting.

TENSILE STRENGTH is that property of a metal which resists such forces as those which tend to pull the metal apart. It is

the force, exerted in pounds per square inch, necessary to break the stock.

Remember that in heat-treating, the heating must be done UNDER CONTROLLED CONDITIONS. This means that you will control the time taken for heating, and the temperature to which the metal is heated. You will also control the time and manner in which the metal is cooled.

Heat-treatment involves the following three steps:

1. Heating to a predetermined proper temperature.
2. Holding or soaking at that temperature for a specified period of time.
3. Cooling to room temperature in a manner determined by the treating process and the metal being treated.

GET IT HOT

The application of heat may be accomplished in numerous ways, depending upon the equipment that you have. Large shops may have salt and lead baths, controlled-atmosphere electric furnaces, or induction furnaces. A small shop such as the village smithy may have only a forge or a torch. You, as a Metalsmith aboard a destroyer, may be called upon to harden and temper a chisel with no means of applying heat other than your oxyacetylene welding torch. On a fleet repair ship, submarine tender, destroyer tender, and at shore installations, you will have plenty of equipment. In addition to your torch, you will have an oil-fired forge, a medium-temperature electric preheat furnace (annealing furnace), and a high-temperature hardening furnace. Both of the furnaces are equipped with controllers, with which you can regulate the speed of heating and maintain any desired temperature within range of the furnace. In addition, these furnaces are equipped with a device for controlling the atmosphere inside them. The controls may be set for a specific atmosphere, such as CARBURIZING, OXIDIZING, or NEUTRAL, which minimizes if not entirely eliminates the possibility of scaling, decarburizing, or burning of the metal.

HOLD IT

Did you ever notice what happens to a baked potato? It is subjected to heat which warms the outside and then cooks through to the center, changing the properties and cooking the potato. In a similar manner, except that the degree of heat may range as high as 2400° F. for some alloys, metal is heated and brought to temperature in the heat-treating operation. The important point to be remembered in heating is the uniformity with which the metal is brought up to temperature. Don't forget that thin sections heat faster than thick ones, just as little potatoes cook faster than big ones.

When you use a salt or lead bath, or an electric or oil-fired furnace, you are assured of getting uniform heating. If you don't have this equipment and have to rely on your torch, or at best a forge, you'll have to be careful that the stock is being heated uniformly. Just getting the metal hot, however, is not going to do the whole job. Many operations in heat-treating specify that the temperature must be held constant for a specified length of time. This is called HOLDING OR SOAKING.

Now when you are baking a potato, you can stick it with a fork to see if it is done all the way through. If it is not, the answer is to bake it some more. Of course, we can't stick a fork in a piece of metal to see if it has heated through, so we have to allow the necessary time for soaking after the proper temperature has been reached. This is called HOLDING. The metal is held at a constant temperature to insure an even and uniform heat throughout. The smaller the section of metal, the less time it will take for the heat to soak through. An allowance of 1 hour per inch of cross section (thickness) is the time recommended for the soaking.

COOL IT OFF

After you have brought your piece of metal to temperature, and held it at that temperature for the proper length of time, you are ready for the third important step—COOLING. In all heat-treating operations the first two steps are identical. The third step, however, will be to cool the metal in a quenching

medium (such as brine) or in a furnace. The results desired will determine the method. The time element, then, may vary from a few moments to 36 hours.

You may be called upon to heat-treat any metal or alloy, but the greater part of your work in the Navy will be with the treatment of low, medium, and high carbon steels. These steels are basically alloys of iron (*Fe*) and carbon (*C*) plus a minimum amount of other elements.

CRITICAL RANGE

Webster says that the word "critical" indicates a crisis or turning point, like the *critical* stage of a fever. Throughout the heat-treatment of steel, as well as of other metals and alloys, you will be face to face with critical points and critical ranges, just as the doctor and patient are face to face with critical points in a fever.

The critical point in a metal is that point at which the most radical changes inside the metal occur. These changes are a result of heating. Each type of metal has its own critical point.

Until you've had a lot of experience as a heat-treater, you won't be able to determine when a piece of metal being heated reaches its critical point just by looking at it. You can be sure that some metallurgical laboratory has determined the critical point for any metal that you'll work on, and you can get the information from a chart or handbook.

The critical range is a temperature range of from 50° to 100° F. above the critical point. Temperatures required for all of the heat-treating processes fall within this range. The critical range, like the critical points for all metals, has been determined in a laboratory and made available for your use in charts and handbooks. Figure 42 is such a chart for heat-treating carbon steel.

You won't be able to heat-treat any odd piece of metal that you may pick up around the shop until you can identify it. In order to heat-treat a metal, you must know its composition. With this knowledge you can determine the critical range from the necessary charts. If you know the composition of the

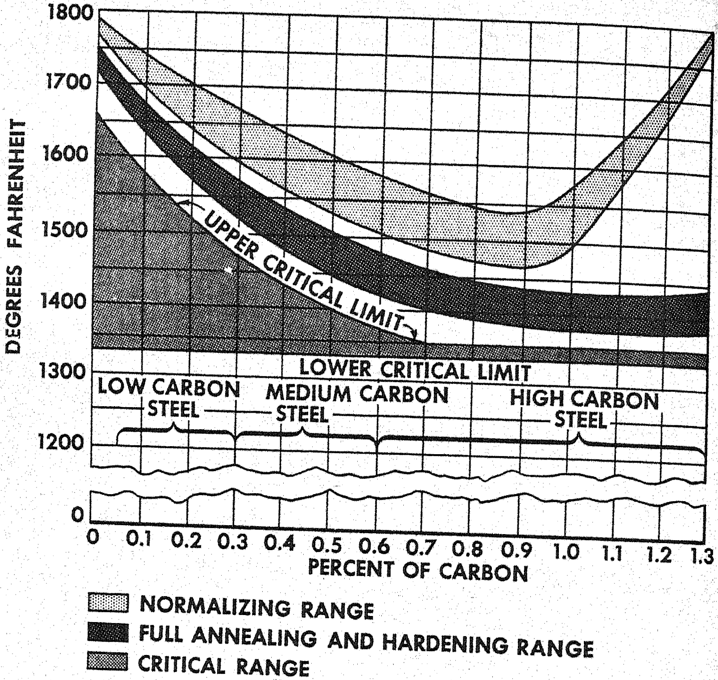


Figure 42.—Temperature ranges.

metal and its critical range, you can then get the property that is needed by the proper cooling or quenching method. It may be necessary to treat some tools or machinery parts several times before they are finally completed. For example, a chisel that has been in service and has been returned to the metal shop for reforging and heat-treating must first be softened (annealed). After forging and rough-grinding the chisel, you will then have to harden it and finally draw it to the proper temper.

It is well to know what goes on inside a piece of steel while it is undergoing heat-treatment, but you are going to be more concerned with the changes that you can see. Color change is one of the most apparent changes. As heat is applied uniformly to a bright piece of steel, no color change is apparent until a

temperature of about 400° F. is reached. At that point a faint straw color appears on the surface. You will notice, as you continue the application of heat, various surface color changes. These color changes continue as the degree of heat increases.

Here's an experiment that will make you a bit more familiar with the color changes that occur as steel heats. Cut a piece of cold-rolled bar stock 2 by 1 by 3/16 inches. If that is not available, brighten a piece of strap iron of approximately those dimensions on an emery wheel. Be certain that the surface is bright and clean. Now heat a fire brick in your forge for about five minutes. Place your test piece, bright side up, on the brick. Watch it carefully. As the heat radiates from the brick to the metal, the color of the metal will change—first a pale straw, and then on up to and through a light blue. As the metal absorbs more heat, the light blue color fades out and no color is visible. Upon further application of heat, your test piece will continue to change color.

If you are the Metalsmith on a small ship, or on a ship that is not equipped with a heat-treating furnace with controllers, color will be the only method you'll have to determine the temperature of the metal you are treating. Practice and experience alone can make you good at estimating temperatures. Color is a rough estimate at best, but you'll have plenty of chances to use this knowledge and experience in times of emergency.

Another visual change which you will observe when the piece reaches a temperature near 1600° F. is SCALING. This scale is identical to rust. You've seen scrap iron that has been exposed to the weather for long periods of time, and you've noticed the burnt crumbling appearance. This is an example of oxidation. Scaling is the same thing—the difference being that it occurs faster than ordinary rusting. At high temperatures this rusting or oxidizing process is greatly accelerated.

At the same time that the surface appearance changes, the internal changes are taking place. If you could see your piece of soft 0.43 percent carbon steel under a microscope which enlarged the view of the section a thousand times, it would look like the view shown in figure 45.

Figure 45.—Microscopic view of soft (unhardened) 0.43 percent carbon steel magnified 1,000 times.

Now, if that same piece of 0.43 percent steel had been heat-treated—hardened but not tempered—and you could get a look at it through the microscope, you would observe considerable change in the grain structure (see figure 46).

Another characteristic of the internal change in metal is grain growth. If you could observe a piece of 0.83 percent carbon

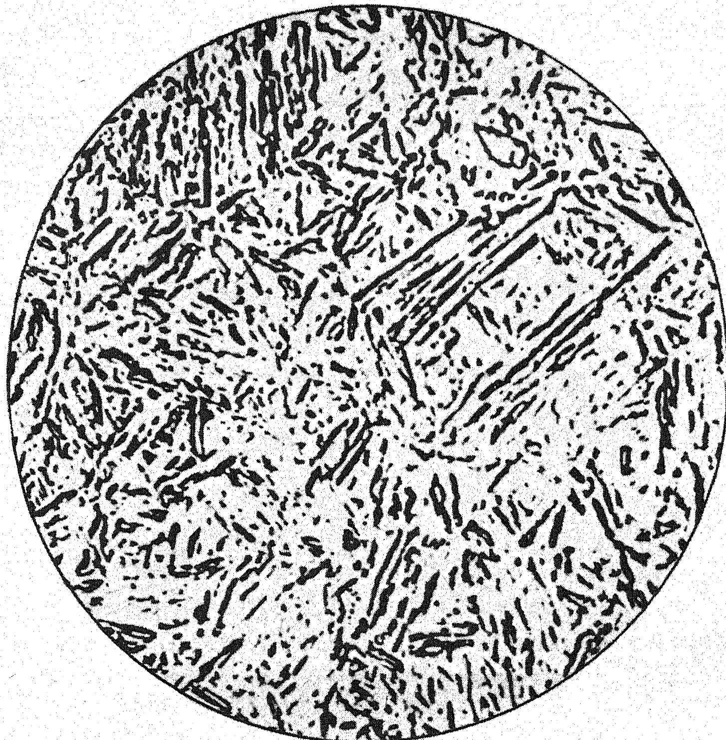


Figure 46.—Microscopic view of hardened 0.43 percent carbon steel not tempered.

steel during heating, you would observe that the grain size is smallest at about 1300° F. or just as it reaches its critical point. The higher the steel is heated above this temperature, the more the grain will grow in size. Figure 47 illustrates grain growth resulting from heat. The fractures of steel show the different sizes of crystals which have resulted from heating the same steel to different temperatures. The specimen at the left was heated to 2300° F. The specimen at the right was heated to the critical point. Those specimens between were heated to temperatures varying from 2300° F. to the critical point.

In all your work as a practical heat-treater, your greatest concern will be the critical point of the metal or alloy you are

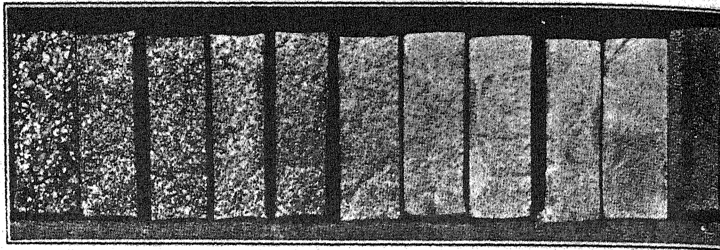


Figure 47.—Grain growth resulting from heat.

treating. You must know the critical point and the alloying ingredients before you start any heat-treating operation. Additional information covering heat-treating for most metals is given in the following table.

If you have special steels or alloys to treat, a letter to the manufacturer will bring you all the information that you need.

FORMS OF HEAT TREATMENT

The most common forms of heat-treating for ferrous metals are: annealing, normalizing, hardening, tempering, and casehardening. As a Metalsmith 3 or 2 you are not going to be held responsible for casehardening, but if you do have the chance to pick up a little practical experience in casehardening under the guidance of an experienced Metalsmith, don't pass up the opportunity.

ANNEALING is used to reduce stresses, induce softness, change ductility, or to improve grain structure. The greatest softness you can get in metal results from heating it to a point above the critical temperature, holding it at this temperature until the grain structure has been refined, and then cooling it slowly. The most important step in annealing is to raise the temperature of the metal to the critical point, as this will remove any hardness that may exist in the piece of steel. Refer to figure 42, and read from the chart the critical point for the particular type of steel that you are working. Any strains that may have been set up in the piece of steel by previous heat-treatment will be eliminated when you have heated the steel to its critical point

PRIMARY HEAT-TREATING HINTS

METAL	ANNEALING TEMP.	COOLING	PREHEAT	HARDENING TEMP.	QUENCHING MEDIUM
Carbon steel*	50°–100° F. above critical temp.	Slow		50°–100° F. above critical temp.	Water or oil
Aluminum	752° F.	Air		Cold work	
Copper	932° F.	Rapid		Cold work	Water.
Monel	1400° F.	Rapid		Cold work	Water.
Brass	600°–1300° F.	Slow			
Bronze	1400° F.	Air			
Stellite (Cr–Co–W)	2100°–2150° F.	Rapid			
Copper Nickel	1400°–1450° F.	Rapid			
Stainless steels:					
Cr. 18% Ni. 8%	2000°–2200° F.	Rapid			
Cr. 25% Ni. 20%	2000°–2100° F.	Air			
Cr. 8.5% Ni. 22%	1650°–1750° F.	Slow			
Cast irons	50°–100° above critical temp.	Slow			
High speed steel	1600°–1650° F.	Slow to 1000°	1450° to 1600° F.	2250°–2350°	Oil.

*Carbon steels with which you will come in contact in the Navy. Other carbon alloy steels may require varied treatment.

and restored it to its lowest hardness by slow cooling. In annealing steel, you must remember never to heat it to more than 50° to 75° F. above its critical point. Also, if the piece you are working is large, you are going to have to allow sufficient time for the heat to penetrate.

Steel is usually annealed for the following purposes:

1. To increase its ductility.
2. To refine the crystalline structure and to remove stresses.

Ductility is increased by decreasing hardness and brittleness. In other words, when steel is made softer it is more workable. You can also alter other physical properties of a piece of steel, such as its magnetism or electric conductivity, by annealing.

Refining the crystalline structure of steel simply means changing the internal structure by a process of heating and cooling in such a manner as to remove any stresses or strains that may have been set up in a piece of steel by cold working, forging, welding, or usage.

Remember that in annealing, as in all heat-treatment, the temperature of the operation and the rate of cooling depend on the material that you are treating and the purpose for which you are treating it.

If you have heat-treating equipment aboard your ship, the process of annealing can be done with accuracy. Just check the chart for the critical point of the percent carbon steel you are about to work. Heat it slowly in your furnace to a temperature 50° to 75° F. above the critical range. Hold (soak) the piece for a sufficient period of time to insure uniform temperature throughout the piece—about 1 hour for each inch of sectional thickness (small tools require only 30 minutes). Now, assuming that you have heated the part to be annealed to the proper temperature, you'll have to decide on a method for cooling. If you want a full anneal, that is, if you want the piece to be as soft as is possible, seal the piece in the furnace and allow it to cool down to room temperature with the furnace. This may take 24 to 36 hours. The other method that is commonly used is called packing. To pack, remove the piece from the furnace, being careful to avoid drafts, and bury it in an annealing box filled with asbestos, or slaked lime, making sure that you leave

the piece completely covered 16 to 24 hours, depending upon its size. Be sure that the material in your annealing box is perfectly dry.

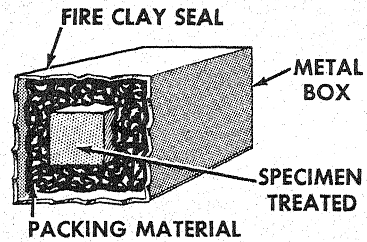


Figure 48.— Cross sectional view of annealing box.

To avoid scaling or decarburization (burning), you may have to use the box-annealing (pack-annealing) method for some materials. In this method, you place the piece to be annealed in a metal box. Completely surround the piece with cast iron chips and seal the box with fire clay. The box is then placed in the furnace, heated, held, and allowed to cool in the sealed furnace as previously described for steel. This method is used when surface finish is important.

You may not be fortunate enough to have an annealing furnace. In that case, you will have to use a forge or a torch when you have annealing to do. The operation is the same, but you'll have to exert a lot more caution in heating and holding. On your furnace, you set your controller and it insures the correct temperature. With a forge or torch, you are the controller. You'll need to be especially careful to:

1. Avoid overheating the metal. Overheating causes increased grain size and there is danger of burning the metal and decarburizing the surface.
2. Have everything ready to make the transfer from the forge to the annealing box.
3. Make that transfer as quickly as possible, avoiding drafts of air which cause uneven cooling. Uneven cooling is responsible for warpage, strains, and fractures.

Although steel is the material which you will most often be called upon to treat, it is not the only material. Other alloys require different annealing operations. An outstanding example of an alloy that requires an entirely different treatment for annealing is duralumin. Duralumin is composed of 94 percent aluminum, 4 percent copper, and approximately 1 percent each of magnesium and manganese. This alloy is annealed by first heating it to 986° F. It is then cooled rapidly by quenching in water. For a short period of 45 minutes it is in a plastic condition and can be bent, rolled, and worked cold. Beyond this interval it becomes hard and cannot be further worked without repeating the heat-treatment. This example emphasizes the need for knowing exactly the material you are treating.

Annealing is a frequent and important process for softening nonferrous alloys and pure metals after they have been hardened by cold work. Annealing restores the ductility, relieves internal stresses, controls grain size, and, in the case of copper and aluminum, restores electrical conductivity. Following is a list of the more common metals with instructions for annealing each:

1. Copper: Heat to 925° F. Quench in water. Temperatures as low as 500° F. relieve most of the stresses and strains.
2. Aluminum: Heat to 750° F. Cool in open air. Reduces hardness and strength but increases electrical conductivity.
3. Zinc: Heat to 400° F. Cool in open, still air.
4. Brass: Annealing to relieve stress may be accomplished as low as 600° F. Fuller anneals may be accomplished with increased temperatures. Larger grain size and loss of strength will result from too high temperatures. Do not anneal at temperatures exceeding 1300° F. Brass should be cooled to room temperature slowly. Either wrap the part with asbestos cloth, or bury in slaked lime or other heat-retarding material.
5. Bronze: Heat to 1400° F. Cool in open furnace to 500° F. or place in a pan to avoid uneven cooling caused by drafts.
6. Nickel-copper alloys, including monel: Heat to between 1400° and 1450° F. Cool by quenching in water or oil.
7. Nickel-molybdenum-iron and nickel-molybdenum-chromium-iron alloys (known commercially as stellite): Heat

to between 2100° and 2150° F. Hold at this temperature a suitable time, depending on thickness. Follow by rapid cooling in a quenching medium.

8. Stainless Steel (Cr. 18% Ni. 8%): Full anneal—heat to between 2000° and 2200° F. Cool rapidly. Partial anneal —heat to between 1600° and 1700° F.
9. Stainless Steel (Cr. 25% Ni. 20%): Heat to between 2000° and 2100° F. Do not soak. Cool in still air.
10. Stainless Steel (Cr. 8.5% Ni. 22%): Heat to between 1650° and 1750° F. Do not soak. Cool slowly to room temperature.
11. Cast Iron: Heat slowly to between 800° and 1800° F., depending on composition. Hold at temperature for 30 minutes, and cool slowly in furnace or annealing box.

Remember your first trip up on the bridge? One of the many navigational instruments you saw there was the magnetic compass. Perhaps you noticed the quadrantal spheres, or balls, used to compensate deviation and error of the compass. Before they can do their job correctly, they must be free of magnetism. That's where you come in. Periodically, the Quartermaster will bring these balls to the metal shop for annealing. The balls are made of gray cast iron and the treatment you give them is a partial anneal. Heat the spheres slowly to the proper temperature, hold at that temperature for 30 minutes, and cool slowly in the furnace or the annealing box. This treatment will disperse the magnetic field without the sacrifice of strength of the casting.

The quadrantal spheres are only one application of cast iron heat-treatment. If your purpose for heat-treatment is to relieve stresses and strains set up by welding or other causes, you will use the same treatment as for the spheres; but if your purpose is to soften for machinability, you then use a temperature of between 1400° and 1500° F. Highly alloyed casting may need temperatures up to 1800° F. Care must be exerted in heating and holding to prevent oxidation. In all cast iron annealing processes, slow cooling is recommended.

Ask yourself these questions before you begin any annealing operation:

1. What metal or alloy do I have to treat?
2. What is its critical point?
3. Am I annealing to relieve stress, to aid machining, or to alter magnetic or electrical properties?
4. What upper temperature shall I use?
5. How long shall I "hold" at the upper temperature?
6. Which method and rate of cooling shall I use?

When you have answered these questions and have made all preparations, you are ready for the annealing operation.

NORMALIZING involves a slightly different heat-treatment from annealing, but it may be classed as a form of annealing. It is a process whereby iron base metals are heated above their critical temperatures to get a better solubility of carbon in the iron, followed by cooling in still air. The process removes all strains due to machining, forging, bending, and welding. You can do normalizing only with a good furnace where the temperatures and atmosphere can be closely regulated and held constant throughout the entire operation. A reducing atmosphere will normalize metal with a very small amount of oxide scale; but an oxidizing atmosphere will leave the metal heavily coated with scale. This outside scale will prevent outside hardness in any other hardening process. The term "decarburization" is used to describe this surface condition of metal when it has had a portion of the carbon content of the surface burned out. The effect of decarburization is shown in figure 49.

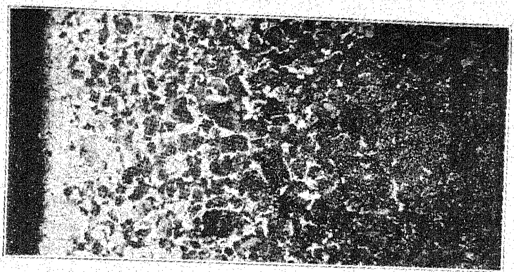


Figure 49. — Decarburized surface of overheated steel.

In the illustration, the light-colored left edge shows the decarburized skin of the piece of steel. This condition of the

skin of metal is not confined to the normalizing operation, but can and does occur in heating for annealing and hardening as well. It is well to bear in mind that a piece of steel designed for a particular job will have to be machined to certain dimensions. The machining must remove the decarburized surface without reducing the piece to less than the required dimensions. On the other hand, though, all of the decarburized surface must be removed from the surface of the piece when it has been machined to the required dimensions. Always select an oversized piece of metal which will allow for this machining. This extra metal is called an "allowable tolerance." Remember that you can control this burning or decarburizing considerably by the use of neutral or slightly carburizing atmospheres in the furnace. If you have an oil-fired forge instead of the latest thing in heat-treating furnaces to work with, be sure that you do not have an excessive blast of air going into the firebox. You may have only a multiple-tip heating torch or a Hauck Burner. If so, you then must exercise great care to avoid decarburization.

Some alloys, such as the chromium types, are normalized prior to regular heat-treatment operations. Normalizing softens steel somewhat, but it does not affect its strength to any great extent.

The precautions applicable to annealing also apply to normalizing. These are the steps to be remembered:

1. Heat the piece to be normalized to a point 50° to 100° F. above its critical point.
2. Hold the piece at this point until the heat has had time to soak through to the center of the section. Avoid prolonged soaking of the metal at high temperatures as this will cause the grain structure to enlarge.
3. Remove from the furnace and cool in still air. Avoid drafts. They will result in uneven cooling which will again set up strains in the metal.

HARDENING of metals and alloys can be done in several ways. Copper is hardened by rolling or working, but steel requires a different process. To harden steel, you must heat the metal to a little more than its critical temperature, then cool it rapidly

by quenching it in oil, water, or brine. This treatment gives the steel a fine grain structure, extreme hardness, greater tensile strength, and less ductility. Steel, after being hardened, is generally too brittle for most practical uses, although this treatment is the first step in the production of high strength steel.

If you are to harden steel with success, you must observe the following factors:

1. CONTROL OVER THE RATE OF HEATING.—Control is necessary specifically to prevent cracking of thick and irregular sections.
2. THOROUGH AND UNIFORM HEATING TO THE CORRECT HARDENING TEMPERATURE.—The length of time required for soaking will depend upon the size of the section of metal being treated.
3. CONTROL OF FURNACE ATMOSPHERE.—Certain steels require accurate control of the atmosphere to prevent scaling and decarburization.
4. SUITABLE QUENCHING MEDIA.—A good quenching medium must have the correct heat-capacity, viscosity, and temperature if it is to harden the metal adequately without cracking it.

Most of your work in hardening is going to be with carbon tool steels. These steels contain from 0.7 to 1.5 percent carbon. The treatment of all steels in this class is the same except for the variation in critical point. The critical point in hardening, as in all heat-treating, determines the temperature to which the steel must be heated. You can determine this point from the critical range temperature chart for carbon steel shown in figure 42. Ordinary carbon steels are heated to between 1350° and 1500° F. These steels are supplied in the unhardened condition, in various sizes and shapes, such as rods and bars. They can easily be shaped into the desired form by forging or machining. In its unhardened state, tool steel is of little value; but when it is properly hardened and tempered, it takes on properties that enable it to cut other metals. The common cold chisel is a tool that demonstrates the properties of hardness and toughness

that can be developed in carbon steel through the hardening and tempering treatments. Carbon tool steel is hardened by slow heating to a point 50° to 100° F. above the critical temperature, and sudden cooling by quenching in water or oil. It is well to remember that the critical points of steel vary with the alloying ingredients. In carbon tool steel, the higher the carbon content of the steel, the lower the critical point.

QUENCHING is a process of rapid cooling of heated metal by placing the piece of metal in water, oil, or some other quenching medium. Any solution used for the cooling of metal in the heat-treating process is referred to as a quenching medium. A number of liquids may be used for quenching steel. Both the quenching medium and the form of the bath depend largely on the nature of the work to be cooled. It is important that you have enough of the medium to cool your metal without changing the temperature of the bath. This is especially important when you have a number of pieces to quench, one after the other.

It is hard to keep steel from warping and cracking during the quenching process because certain parts of the metal cool more rapidly than others. When the change in temperature is not uniform, internal strains are set up which may be sufficient to cause warpage or cracking. Odd or irregularly-shaped pieces are more likely to be affected by internal strains than are even sections. Forging and machining also may set up internal strains in steel parts and it is therefore advisable to normalize these articles before attempting to harden them. To reduce the tendency of steel parts to warp you should pay special attention to the following recommendations:

1. Dip the article to be quenched into the bath. Never throw it in or allow it to lie on the bottom of the bath. If you let the part lie on the bottom of the bath, it is likely to cool faster on the top than on the bottom, thus causing it to warp or crack.
2. The part that you quench should never be allowed to remain still in the bath as the heat will cause a coating of vapor to be formed around the part which will prevent it from cooling rapidly. Keep it moving. This stirring allows the bath to convey the heat to the atmosphere.

3. The piece should be quenched in such a manner that all of its parts will be cooled uniformly and with the least possible distortion. Such parts as a gear wheel or shaft should be quenched in a vertical position.
4. Odd shaped steel parts should be dipped, or immersed, in such a manner that the thickest sections will enter the bath first.

QUENCHING MEDIA commonly used are fresh water, salt brine, and oil.

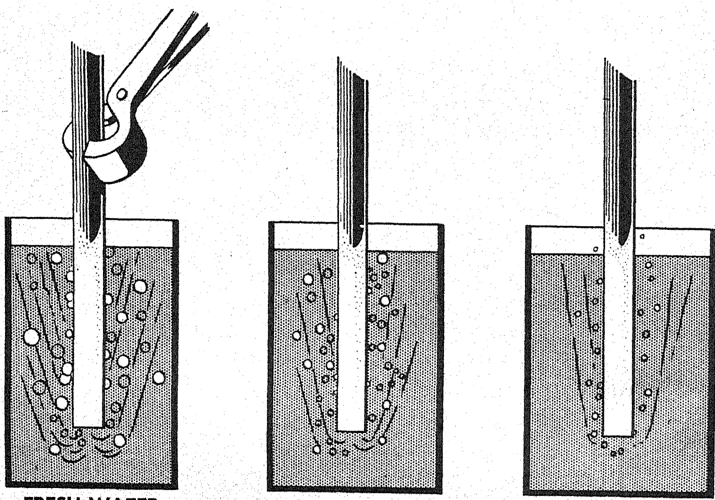


Figure 50.—Effects of quenching media on steel.

WATER is often used as a quenching medium. It is not ideal, however, because of the bubbles which form on the surface of the tool or part being quenched, especially in holes or recesses. These bubbles retard the cooling process and cause soft spots which are likely to weaken the steel. If you do use water, be sure to keep the object being quenched moving to avoid as much as possible the formation of gas around the metal part. The water bath should be kept at about 70° F., as extremely cold water may warp or crack the steel, and water above this temperature will not produce the required hardness.

SALT BRINE is much better for a quenching bath than fresh water. When the brine is quiet (not in motion) it is referred to as still brine. The most satisfactory brine bath is made by dissolving ordinary salt in water until a 5 to 10 percent solution is obtained. The salt in the water causes the water to "take hold" and wet the heated steel tool or part all over immediately. This wetting causes the quenching to proceed uniformly. Brine also "throws scale" better and usually gives you a cleaner tool or part.

OIL is slower-acting than water. This characteristic makes its use an advantage when quenching heated steel as it will greatly reduce the tendency of the steel to warp or crack when quenched. Unfortunately, though, parts made of high carbon steel will not develop their greatest possible hardness when quenched in oil unless they are quite thin. Oil is best to use, however, when it will produce the required hardness.

Oil quenches should have a high flash point, low viscosity, and a constant composition. They should be kept at temperatures of from 140° to 160° F.

QUENCHING BATHS may be made with agitators to keep the quenching media circulating, or they may be designed for continuous circulation by means of a circulating pump. You'll have to keep your bath at the proper temperature by the best means at your disposal. For example, if your quenching bath is too cool, you can heat it with hot pieces of scrap metal until the proper temperature is reached. Here are a few points that you should know:

1. The quenching rate of the medium drops as its temperature rises.
2. Near the boiling point, the quenching medium has less than 10 percent of the quenching rate, or the ability to cool, that it has at 68° F.
3. More heat will be carried away if the piece is kept moving about in the bath. This carrying away of heat is called heat dissipation.

Certain of the iron base alloys are classed water-hardening while others are classed oil-hardening. Some of the high speed

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steels are called air-hardening. Again, as in any phase of heat-treating, you must know just what kind of metal or alloy that you are working with. If you make the mistake of quenching an oil-hardening tool in water, you will in all probability crack the tool. The action of the faster rate of cooling of water is too harsh and abrupt for alloys classed as oil-hardening metals. Plain carbon steels have a high rate of cooling, so cooling by quenching can't be too fast for them. Additions of alloying elements to steels lower their critical cooling rate, and thereby require the use of a quenching medium that has a slower cooling rate.

If there is any doubt in your mind about the method of heating and cooling required for a particular piece of metal, your best clue is to find out the stock number for that particular piece of metal. From the stock number you can find the Navy specifications for that stock. The specifications will give you the information that you need concerning the alloying constituents and tensile strength of the metal. From this information you can judge the critical temperatures, and the best method for heating and cooling by comparing the metal in question with another metal, for which you know the proper treatment.

Hardness, distortion, and internal stresses are all results of the cooling rate. Oils, therefore, produce less distortion and fewer stresses in steel than other quenching media. Mineral oils are generally used for quenching as they are less expensive than other oils. Also they are of a more stable nature than other oils; that is, they are not so subject to decomposition.

TEMPERING, also called drawing, is a process which is generally applied to steel to relieve the strains that are brought about during the hardening process. Tempering is done by heating the hardened steel to a temperature below the critical range, holding this temperature for sufficient time for it to completely penetrate the piece, and then cooling in water, oil, or air. In this process, as in the other heat-treating processes, as you gain one property you lose others. For example, in tempering you improve the ductility and toughness, but in doing this you lose some of the tensile strength, yield strength, and hardness.

The temperature to which you will reheat hardened steel is determined by the degree of hardness and toughness desired. The tempering range is from 400° F. to a point just below the critical point. (The upper temperature is usually about 1000° F.) Tools for which cutting edges are desired are not tempered above 600° to 700° F. A file is a cutting tool which may be very hard and brittle. Since it receives little shock or pressure, brittleness is no disadvantage. A chisel, on the other hand, is subjected to tremendous shock, and it must be tough—not brittle—and its head must be soft to receive the blows. You'll soon learn by trial the degree of heat to which a tool must be tempered. You can be guided by the following table which gives the tempering heats for various tools in degrees Fahrenheit.

Temperatures for tempering various tools

DEGREES FAHRENHEIT	TOOL
400°	Hammer faces, machine cutting tools.
460°	Taps and dies.
480°	Punches, reamers, dies, knives.
500°	Twist drills.
520°	Drift pins, punches.
540°	Cold chisels.
550°	Screw drivers, springs.

Again we have the problem of controlling the heat. In this case, it is the tempering or reheat temperature. If you have a tempering furnace you only have to set the controlling devices. If you don't have one, you must improvise and complete the hardening and tempering treatment as best you can. Several methods of reheat are possible in any sort of shop setup. You will of course have to use what you have. One method of reheat is the firebrick method. You used it to run out the heat color earlier in this chapter. These heat colors will be your only guide to temperature, when you use reheat methods of this type. Another good way of reheating for tempering is shown in figure 51.

You have a metal box filled with sand. The source of heat is an oxyacetylene or other type of torch. The hardened tool,

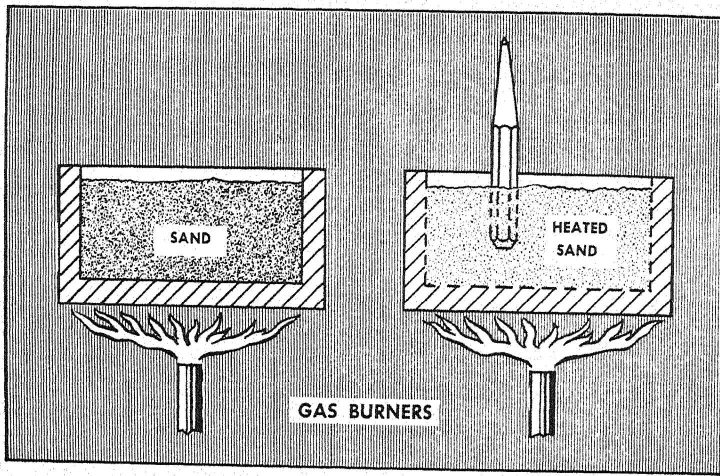

Figure 51.—A method of reheat for tempering chisels, punches, etc.

in this case a center punch, must have a bright clean surface or the heat colors won't indicate the true temperature. First, therefore, rub the tapered end of the punch briskly with emery cloth until it is bright and clean. Then insert it in the hot sand, head down. The heat of the sand is absorbed by the head-end of the tool and travels up to the point by conduction. As more and more heat is absorbed by the tool the point gets hotter. You will notice the color change on the brightly polished end. When the desired temperature is reached, the color indicating that temperature appears on the point of the tool. This temperature should be about 480° F., or a deep straw color. Now remove the punch, using a pair of "pick-up tongs" (see figure 348) and quench it. This is done to prevent more than the desired amount of heat from reaching the point. Because of the varying amounts of heat that have been attained in the tool from head to point, a varying degree of hardness will be present in the tool. The point will be hard and capable of penetrating metals, the shank will be tough, and the head will be soft enough to withstand the continued blow of a hammer.

Another method is often used with chisels. Bring 2½ or 3

inches of the cutting edge of the tool up to hardening temperature. Quench the tool by plunging about 1½ or 2 inches of the heated end into the quenching medium, jiggling rapidly in an up-and-down and forward-and-backward motion at the same time, being sure to keep the point immersed ½-inch in the quench tank (figure 52) at all times.

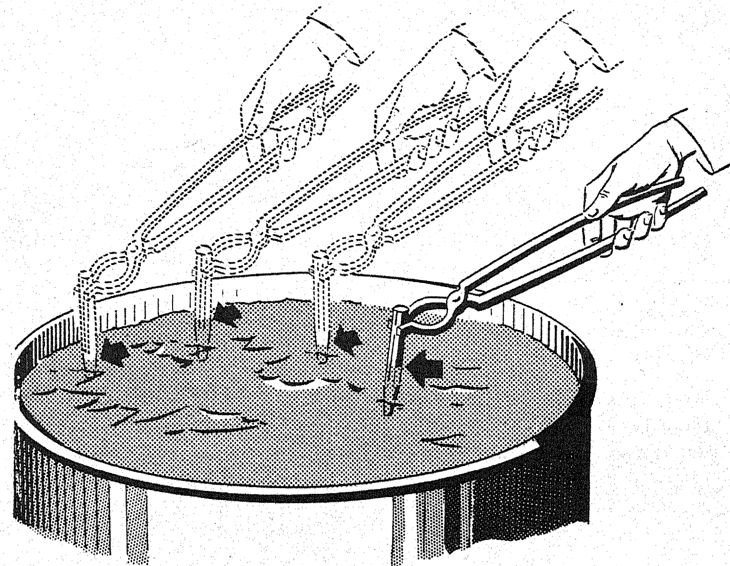

Figure 52.—Quenching a chisel.

When the metal is cooled down to a black heat (900° to 950° F.), remove the tool from the quench tank, quickly polish the tapered end with an emery board (figure 53), and watch the temper color "run out" until the desired color appears (usually a dark blue). Quench the entire tool to stop further heating of the cutting edge.

It is well to remember that every chisel you see is not a water-hardening chisel. Many are manufactured from special alloys and are oil-hardening. Most chisels of this type have directions for treating stamped on the shank as follows: *1350 W 400* or *1600 O*. The first means to heat to 1350° F., quench in water, and temper at 400° F. The second means to heat to 1600° F.,

and quench in oil. It isn't necessary to temper this tool, as it is a special alloy. Other alloy chisels will have different directions stamped on the shank, which is another reason why you must pay attention to the rule. Know the metal you are working! Generally it is safe to assume that an unmarked chisel is a carbon steel water-hardening tool, but give it a spark test to identify it (see chapter 5).

TOUGHENING: The only difference between this operation and tempering is that higher drawing (reheat) temperatures are used (700° to 1300° F.) in toughening. This operation is used when the property of hardness is unimportant and shock-resistance and toughness are desired.

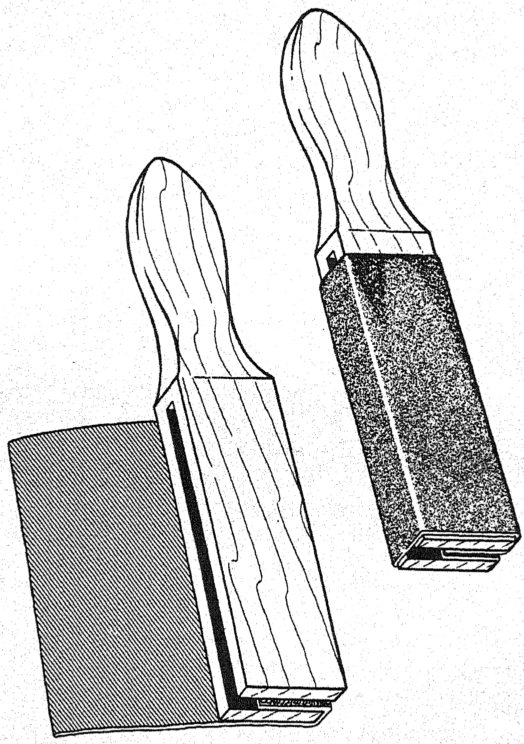

Figure 53.— Emery board.

Equipment needed for heat-treating consists of a suitable means for bringing the metal to the required temperature, a temperature measuring device, and a quenching medium. Heat may be supplied by a forge or welding torch; however, you'll find the job a lot easier done and a lot better done if you have a heat-treating furnace to work with.

The equipment that you have will determine to a great extent the manner in which you perform the various heat-treating operations. Your method of temperature control will greatly influence the results that you will obtain. The more rigid the control you are able to maintain, the more uniform your work will be. Most likely you won't have all of the most modern equipment with which to work, and if this is the case, you will have to depend on your eye to judge heat. Surprisingly good work is done by experienced heat-treaters using the "eye of judgment." With sufficient experience, you too can become adept at this method of determining temperature.

Fleet repair ships are equipped with either oil-fired, gas-fired, or electrically heated air furnaces capable of reaching temperatures up to 2400° F.

OIL- AND GAS-FIRED FURNACES are so constructed that the fire box is inclosed in a casing of steel plates, electrically welded together and mounted on a steel frame. The lining of the furnace is made of firebrick, insulated by a couple of inches of magnesia. The magnesia lets the firebrick expand without danger of damaging the steel casing. The heating chamber is made of semirefractory brick which allows for quick heating. The hearth plates are usually made of heat-resisting alloy with suitable flanges for holding the work in place. Furnaces are made in such a way as to keep the same temperature throughout all parts of the heating chamber.

ELECTRICALLY HEATED FURNACES are found most frequently aboard Navy ships. Usually the heat-treater aboard the modern submarine tender will have two heat-treating furnaces like the one shown in figure 54.

Electrically heated furnaces have the advantage of being

quiet, clean, and constant in operation. The heating element of an electric furnace will be either of the metal or carbon-

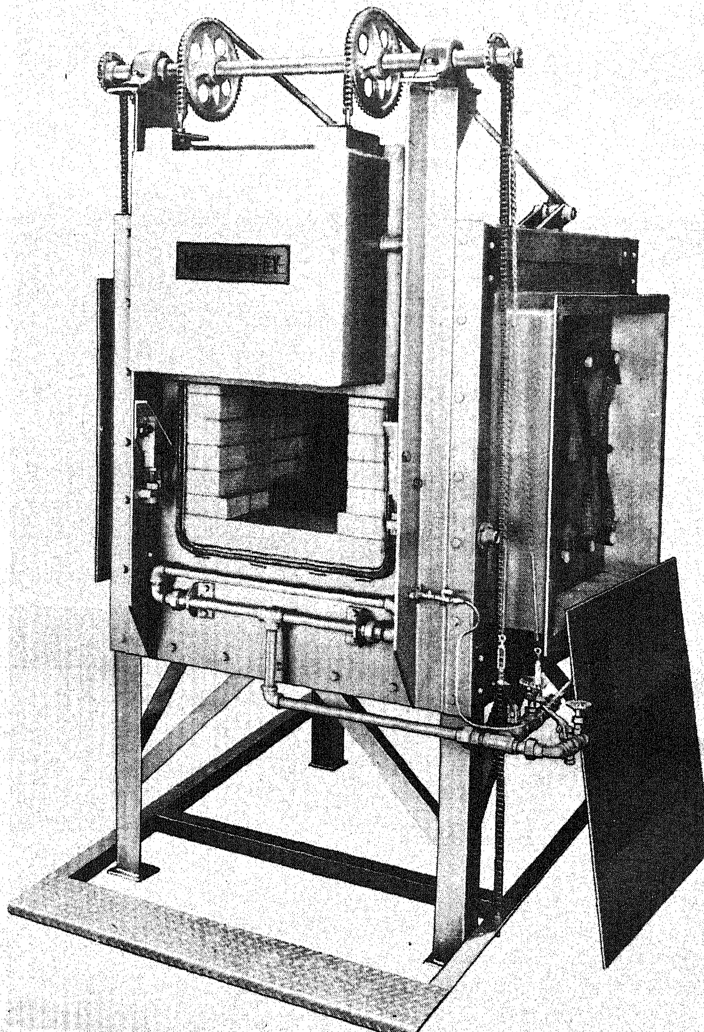

Figure 54.—High temperature controlled atmosphere box furnace.

resistor type. Metal resistors are used where temperatures don't go over 2000° F. Carbon resistors are used for higher temperatures.

If your ship happens to have two furnaces, one of them is most likely used for low-temperature operation. Most heat-treatment can be done in this furnace. The other is a smaller, but higher-temperature furnace, capable of heating to the high temperatures necessary for some of the high speed and special alloy steels.

BATH FURNACES are often used for small parts that have been machine-finished that HAVE TO BE heat-treated. Parts that are too large to be treated in a closed furnace may be treated in a bath furnace. A bath furnace is simply a melting pot filled with molten salt, lead, or oil, and surrounded by fire brick. The bath is kept at the required temperatures by means of electrical-resistors. Figure 55 is a schematic drawing of a bath furnace.

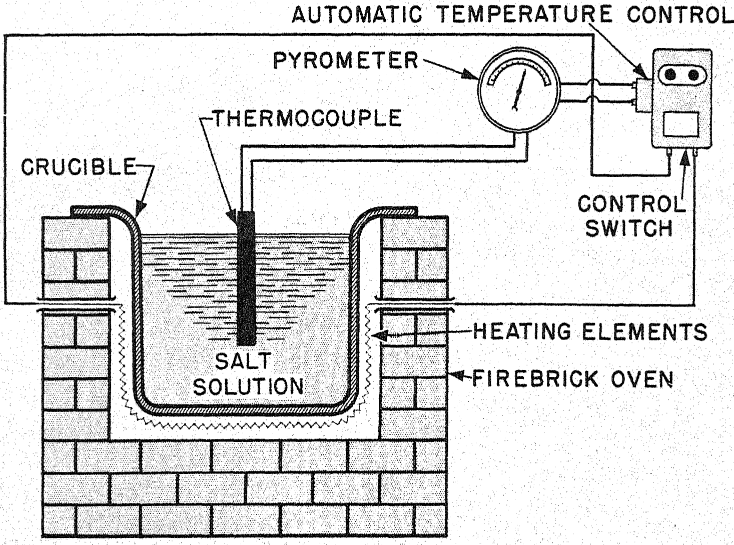

Figure 55.—Salt bath furnace.

Lead and oil bath furnaces are used principally for tempering, while salts may be procured for any temperature range. However, it is well to remember that low-temperature tempering salts are not capable of withstanding temperatures needed for high-alloy steel hardening. Parts heated in the salt bath are free from scaling, but you'll have to be very careful to remove all traces of the salt after the treatment.

Generally, shops equipped with salt bath furnaces will have three furnaces in addition to the lower heat tempering baths that may be available. The temperature ranges for the three baths will be as follows: 1000° to 1550° F.; 1450° to 1950° F.; 1800° to 2350° F. Considerably less time is required for heating with the bath furnace than with air furnaces. When the salt bath furnace is used, the piece is completely immersed in the solution. This excludes air from the piece so no scaling can occur, and the piece will be bright and clean.

DEVICES FOR MEASURING AND CONTROLLING TEMPERATURE are very important. Temperature variation of a few degrees one way or the other may seriously affect the physical properties of the metal you are working. In order to get good results you'll use a thermoelectric instrument known as a pyrometer to measure the temperature of the metal being heated.

A PYROMETER consists of a thermocouple, extension leads, and a meter. It works like this. If you twist or weld two wires made of different metals together and heat them, you will generate an electromotive force or voltage. Now you can measure this voltage by connecting the cold ends of the wire to a galvanometer that is sensitive enough to read in thousandths of a volt. Here is where mathematics comes in. The voltage that you have measured is proportional to the difference in temperature between the hot and cold ends. In other words, the hotter the wires get, the more voltage is generated. Now, as the pyrometer has been marked off in degrees instead of electrical units, it measures heat.

The thermocouple used in pyrometers for measuring temperatures up to 2000° F. is generally of lower-priced iron, copper, nickel, or chromium. The more expensive platinum and rare metal combination may be used up to a temperature of 3000° F.

The thermocouple is the portion of the pyrometer that is inserted in the heat-treating oven to measure temperature. In bath furnaces the thermocouple is inserted in the molten solution itself.

Alloy extension leads are made of the same material as the couple. In effect, you might consider the thermocouple as extending from the furnace to the meter. By the use of leads, you can put the meter far enough away from the furnace that the cold ends won't be affected by the sudden changes in temperature. These leads are carried in parallel and are covered with heat-resisting insulation.

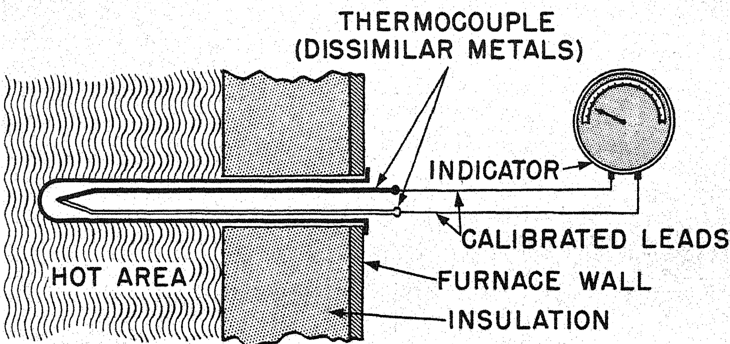

Figure 56.—Diagram of a pyrometer.

The meter in the pyrometer does not really indicate the temperature of the hot end of the thermocouple, but registers the difference in temperature between the hot and cold end. This means that the temperature of the cold end has to be known and held constant. This is taken care of automatically, either by a thermostat which operates a control spring to make the correction automatically, or by a zero adjuster which you must operate by hand.

Pyrometers may be of either the indicating or the recording type. The indicating type of pyrometer must be read while the heating is being done. The recording type makes a permanent

record of the temperature range throughout the heating operation. On modern furnaces you'll find pyrometers which you can set at any desired temperature to regulate the heating. An instrument of this kind is called "controller potentiometer pyrometers." Many gas and oil-fired furnaces and most electric furnaces are equipped with controllers which regulate and maintain any desired heat within range of the furnace design. Figure 57 shows a controller box.

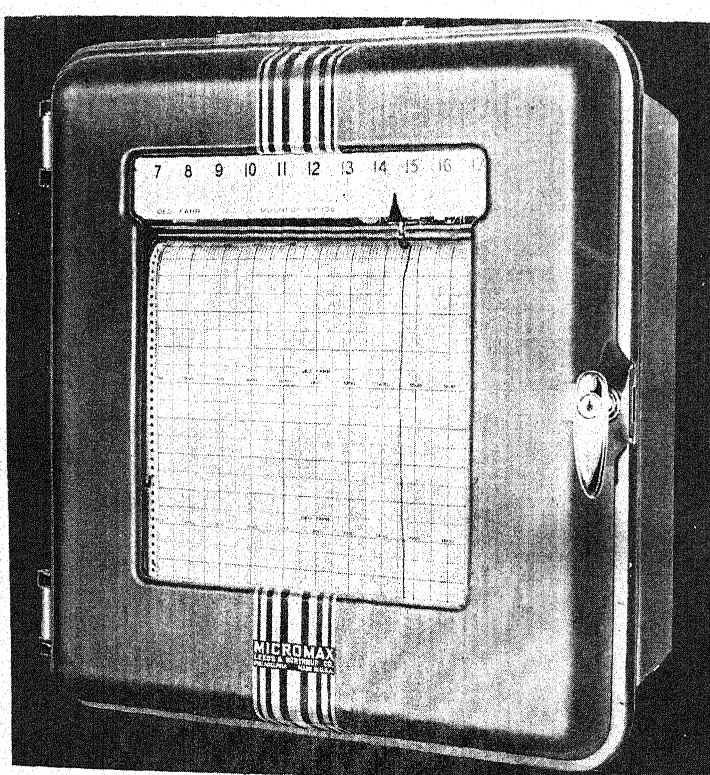

Figure 57.— Controller box.

Take a look at the controller on your furnace. If you need additional information, and you will, break out the instruction

manual furnished by the manufacturer. The log room or the repair office has instruction manuals for every piece of equipment in your shop. Study them and become familiar with the installation aboard your ship or station.

EQUIPMENT FOR QUENCHING BATHS consists of tanks, circulating pumps, and coolers. Tanks must be large enough to allow the liquids to remain at about room temperature. If you do a lot of quenching, you will probably have circulating pumps and coolers to keep fairly constant temperatures.

ATMOSPHERE CONTROL

Proper atmosphere control is essential to good heat-treating. Some heat-treating furnaces have an atmosphere control unit attached. Figure 59 shows a furnace of this type.

A cross sectional view of the controlled atmosphere hardening furnace is shown in figure 58. The construction of all air furnaces is similar, but you can find the exact details of the con-

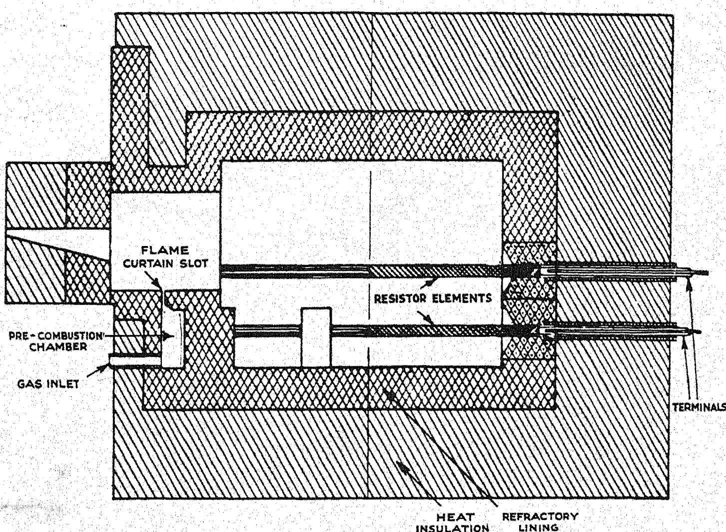

Figure 58. — Sectional view of controlled atmosphere hardening furnace.

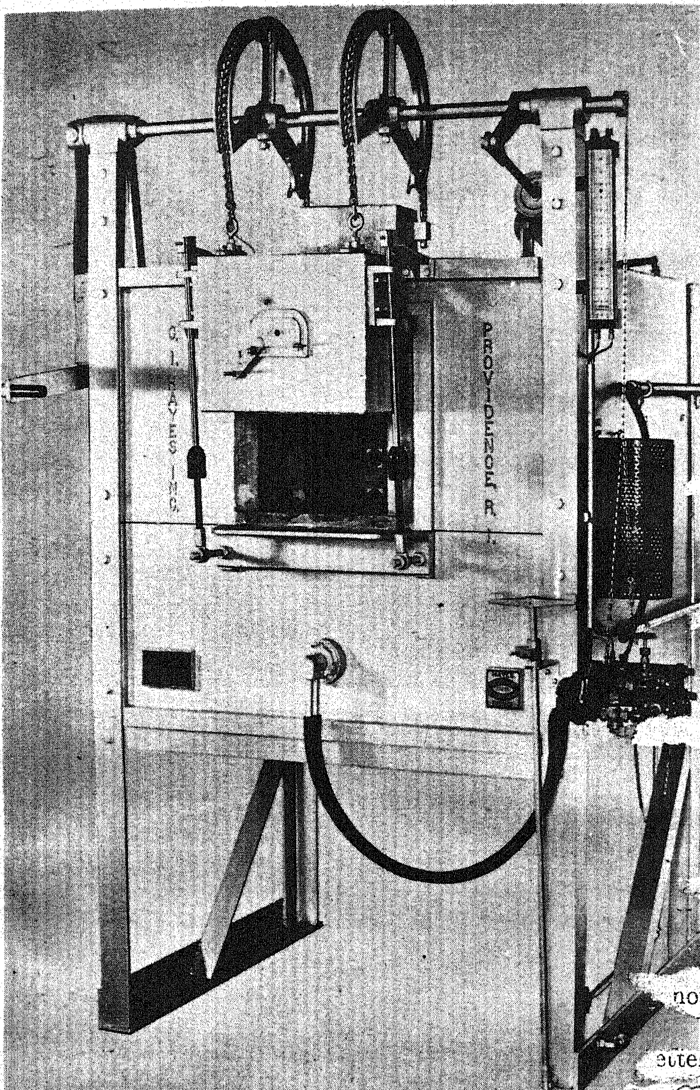

Figure 59 — Controlled atmosphere hardening furnace.

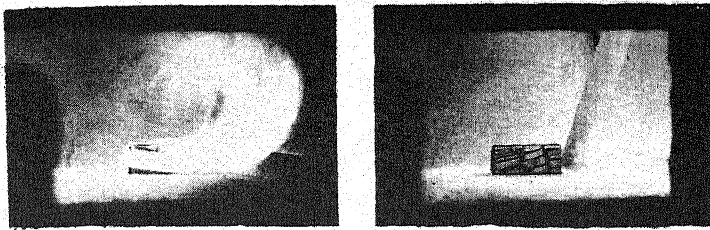

Figure 60. — Burning wood cube to determine furnace atmosphere.

struction of your furnace in the manufacturer's instruction manual along with instructions for operating the furnace.

The main purpose of atmosphere control is to keep the metal from oxidizing. Either a neutral or slightly reducing atmosphere will serve this purpose. A neutral atmosphere is one which has no excess of either fuel or air. A reducing atmosphere has an excess of combustible gases. It is the oxidizing atmosphere, which contains an excess of air that must be guarded against.

After a little experience you will be able to judge the atmosphere by the character of the flame. A long, lazy flame indicates excess fuel or a reducing atmosphere, while a blue flame at the burner, short and "sharp," indicates an excess of air or oxidizing atmosphere.

Atmospheres can also be judged by observing the smoke, flame, and burning of small ¾-inch cubes of wood as shown in figure 60. The character of the burning cube changes from that of charring in a reducing atmosphere to that of rapid burning, as the oxygen, or ratio of air to fuel, is increased.

Figure 61 shows the difference in surface appearance between a high speed cutter treated in a reducing atmosphere and one treated in an oxidizing atmosphere.

To change the atmosphere from oxidizing to neutral or to slightly reducing, increase the ratio of fuel to air. On oil- or gas-burning furnaces this is done by adjusting the fuel and air valves which control the heat of the furnace. On the electric furnace, atmosphere is adjusted by fuel and air valves on an atmosphere control unit attached to the furnace.

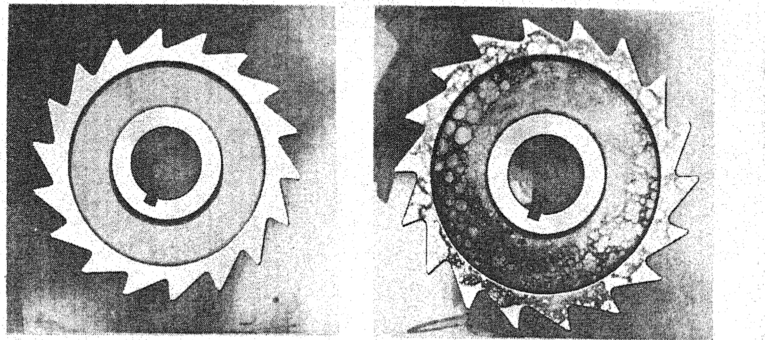

Figure 61. — Cutters hardened in oxidizing and reducing atmospheres.

Each steel has its correct atmosphere.

1. High-speed steel—a reducing atmosphere (excess of fuel).
2. Alloy steel hardening from 1650° to 1800° F.—a neutral atmosphere.

   A desirable atmosphere for high-speed and alloy steels may be obtained by pumping an inert gas, such as helium, into the furnace chamber. Helium permits no oxidation or similar chemical action at any temperature.
3. Carbon and low-alloy steels hardening from 1400° F. to 1650° F.—a neutral atmosphere, slightly on the oxidizing side.

HANDS OFF

Better be safe than in sick bay. Treat any piece of metal in the blacksmith shop or heat-treating shop with respect. It could be hot. KEEP HANDS OFF! Just as more people get shot with "unloaded" guns than with loaded ones, more people are burned with "cold" pieces of metal than with hot ones. Better take a check on those fire extinguishers too. A hot piece of metal dropped carelessly can cause a lot of trouble in a mighty short time. Don't forget to watch out for the other people around you. It's your responsibility to make them KEEP HANDS OFF too.

QUIZ

Select the one best answer to each of the following statements.

1. Controlled structural changes within a metal are obtained by —
   (*a*) Shaping.
   (*b*) Machining.
   (*c*) Bending.
   (*d*) Treating with heat.

2. If a metal can be easily drawn, stamped, or hammered out thin, it is said—
   (*a*) To be highly resistant to pulling forces.
   (*b*) To be resistant to scratches, cuts, etc.
   (*c*) To have good ductility.
   (*d*) To have machinability.

3. The term which describes the ease with which metal is turned, milled, planed, etc., is —
   (*a*) Ductility.
   (*b*) Machinability.
   (*c*) Compressibility.
   (*d*) Malleability.

4. The term which best describes that property of metal which enables it to withstand shock, endure strains and stresses, and to be deformed without breaking is —
   (*a*) Toughness.
   (*b*) Hardness.
   (*c*) Ductility.
   (*d*) Tensile strength.

5. The proper order of the three steps in heat-treating, based on predetermined and specified factors; are —
   (*a*) Heating-holding-cooling.
   (*b*) Holding-heating-cooling.
   (*c*) Heating-cooling-soaking.
   (*d*) Soaking-holding-cooling.

6. Holding a metal at a constant temperature for a specified time is called —
   (*a*) Tempering.
   (*b*) Heating.
   (*c*) Soaking.
   (*d*) Hardening.

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7. The internal grain size of steel will be —

   (*a*) Largest at a high temperature.
   (*b*) Largest at the critical point.
   (*c*) Smallest at a high temperature.
   (*d*) Constant throughout all heating temperatures.

8. The process used to reduce stresses, induce softness, change ductility, or refine the grain structure of a metal is called —

   (*a*) Soaking.
   (*b*) Annealing.
   (*c*) Hardening.
   (*d*) Tempering.

9. Ductility of steel can be increased by —

   (*a*) Soaking.
   (*b*) Hardening.
   (*c*) Carburizing.
   (*d*) Annealing.

10. If done in the furnace, the cooling process to obtain a full anneal of steel will take —

   (*a*) One hour for each inch of sectional thickness.
   (*b*) 16 to 18 hours.
   (*c*) 16 to 20 hours.
   (*d*) 24 to 36 hours.

11. If steel is over-heated during the annealing process, the surface may be —

   (*a*) Normalized.
   (*b*) Decarburized.
   (*c*) Soaked.
   (*d*) Case hardened.

12. The cooling process during the annealing of copper is —

   (*a*) Performed quickly by quenching in water.
   (*b*) The same as for steel.
   (*c*) Accomplished by packing.
   (*d*) The same as for aluminum.

13. Magnetism can be dispersed from cast iron by —

   (*a*) Hardening.
   (*b*) Quenching.
   (*c*) Tempering.
   (*d*) Annealing.

14. When a part of the carbon content of a metal surface has been burned out, the term identifying this condition is —

(*a*) Decalescence.
(*b*) Decarburization.
(*c*) Recalescence.
(*d*) Normalization.

15. The first step in the treatment of tool steel is —

(*a*) Hardening.
(*b*) Normalizing.
(*c*) Tempering.
(*d*) Annealing.

16. A process of rapid cooling of heated metal is called —

(*a*) Drawing.
(*b*) Quenching.
(*c*) Normalizing.
(*d*) Carburizing.

17. Hardening of a metal is accomplished by heating to a little more than its critical temperature, then allowing to cool —

(*a*) By packing.
(*b*) By sealing in furnace.
(*c*) Rapidly by quenching.
(*d*) In still air.

18. The quenching medium which greatly reduces the warping tendency of steel is —

(*a*) Oil.
(*b*) Salt brine.
(*c*) Water.
(*d*) Slack lime.

19. Even though frequently used, water is not an ideal quenching medium since cooling is retarded because of —

(*a*) Soft spots.
(*b*) Scale.
(*c*) Bubbles.
(*d*) Soaking.

20. The article being quenched or the quenching bath should be —

(*a*) Kept circulating.
(*b*) Subjected to alternating temperatures.
(*c*) Surrounded with a vapor blanket.
(*d*) At a temperature near the metal's critical point

21. Hardness, distortion, and internal stresses of a metal are the results of the —
   (*a*) Type of preheating.
   (*b*) Postheating methods.
   (*c*) Tempering process.
   (*d*) Cooling rate.

22. Strains due to the hardening process are relieved by a process called —.
   (*a*) Quenching.
   (*b*) Tempering.
   (*c*) Annealing.
   (*d*) Normalizing.

23. Tempering temperatures of hand tools will vary according to the desired degree of —
   (*a*) Hardness and toughness.
   (*b*) Tensile strength.
   (*c*) Ductility.
   (*d*) Yield strength.

24. A good method of reheating for tempering a hand tool is by —
   (*a*) Direct torch application.
   (*b*) Soaking in a molten metal bath.
   (*c*) Conduction in heated sand.
   (*d*) Sealing in a furnace for several hours.

25. A temperature measuring device used on heat-treating equipment is the —
   (*a*) Thermocouple.
   (*b*) Thermometer.
   (*c*) Thermostat.
   (*d*) Pyrometer.

26. The temperature measuring device used on heat-treating equipment indicates the —
   (*a*) Temperature at hot end of thermocouple.
   (*b*) Difference in temperature between hot and cold thermocouple ends.
   (*c*) Temperature at cold end of thermocouple.
   (*d*) Atmospheric temperature.

27. The main purpose of an atmosphere control during heat-treating is to —
   (*a*) Prevent oxidizing.
   (*b*) Normalize internal stresses.
   (*c*) Neutralize poisonous gases.
   (*d*) Reduce combustible gases.

28. A furnace atmosphere which has no excess of either fuel or air is called —

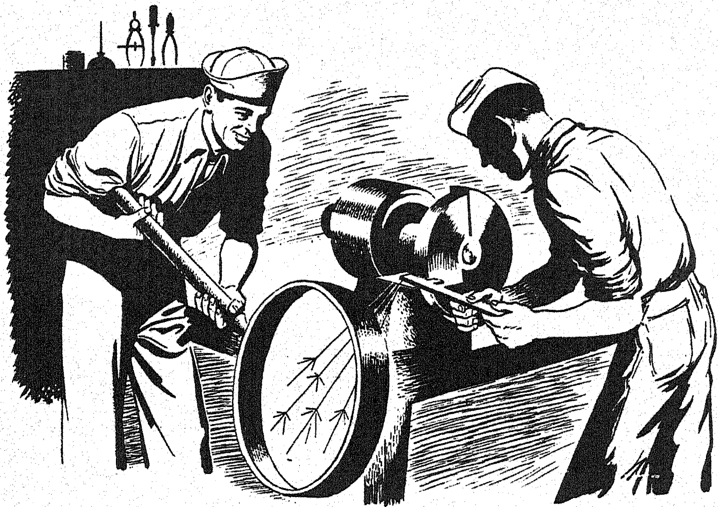
   (*a*) Oxidizing.
   (*b*) Reducing.
   (*c*) Normal.
   (*d*) Neutral.

29. A furnace atmosphere which has an excess of combustible gases is —

   (*a*) Normal.
   (*b*) Neutral.
   (*c*) Reducing.
   (*d*) Oxidizing.

30. A furnace atmosphere change from oxidizing to slightly reducing can be accomplished by —

   (*a*) Increasing the ratio of air to fuel.
   (*b*) Increasing the ratio of fuel to air.
   (*c*) Adding a jet of water to fuel-air supply.
   (*d*) Closing the air valve.



CHAPTER 5

METAL TESTS

Have you ever bitten a coin to see if it was genuine? Or, perhaps you have dropped a coin on the deck to find out what it was made of. Maybe you didn't realize it at the time, but you were testing a metal to find out whether it was nickel, copper, silver, or a substitute for one of those (counterfeit). Tests almost as simple have been devised for the identification of metals. These are the color code, the appearance of the metal, the chip test, the spark test, and the gas-welding torch test. These are discussed in the following pages. Other tests are made to determine the various properties of metals—hardness, brittleness, elasticity, malleability, and the strength of various types. These include the various kinds of hardness tests, tensile strength tests, compression tests, shear tests, bend tests, fatigue tests, and cupping tests. For some of these tests you will have no equipment. But as long as you are a Metalsmith you will be hearing references to metal identification tests, and it's a good idea to know what they are all about.

Some of these tests you will find possible to make with little or no equipment. They will be of such convenience and use to you that you will be using them often.

TESTING FOR IDENTIFICATION

You carry an I.D. card at all times. It tells your name, height, weight, age, the color of your eyes and hair, and gives a likeness of you. These are your characteristics. They identify you from all other sailors. Metals also have identifying characteristics that are sometimes referred to as properties.

The following discussion of properties and tests will help you to identify most of the metals with which you will work.

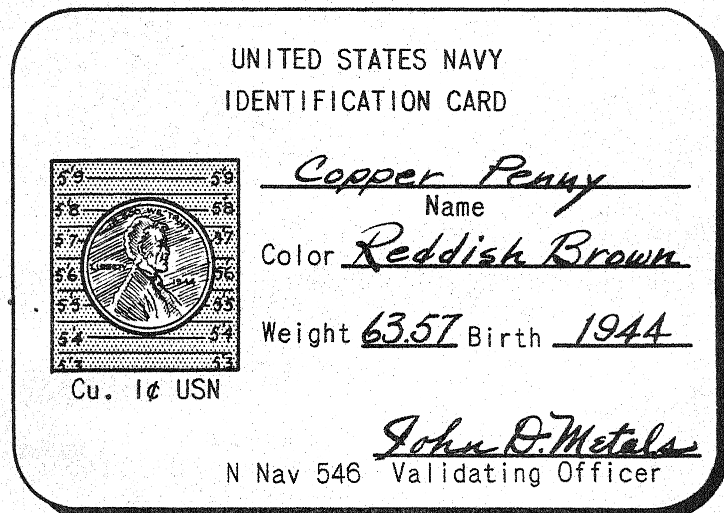


Figure 62.—Metals have an I. D. card.

COLOR CODE

You have five senses: the sense of sight, touch, smell, taste, and hearing. Through these senses you gain experiences. Your senses are your tools. You will use one or more of your senses quite often to identify the metal in question, but most fre-

quently you will be depending upon your sense of sight. You will be able to look at the color of an unknown metal and match it with the color of a known metal, thereby identifying it. The following chart will help you fix the colors of the most common metals in mind.

METALS	OUTSIDE APPEARANCE	NEWLY FRACTURED SURFACE	FRESHLY FILED SURFACE
White cast iron	Dull gray	Silvery white crystalline	Silvery white
Gray cast iron	Dull gray	Dark silvery crystalline	Light silvery gray
Malleable iron	Dull gray	Fine crystalline dark gray	Light silvery gray
Wrought iron	Light gray	Bright gray	Light silvery gray
Low-carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
High-carbon steel	Dark gray	Light gray	Bright silvery gray
Stainless steel	Dark gray	Medium gray	Bright silvery gray
Copper	Reddish brown to green	Bright red	Bright copper color
Brass and bronze	Reddish yellow, yellow green, brown	Red to yellow	Reddish yellow to yellow white
Aluminum	Light gray	Fine crystalline white	White
Monel metal	Dark gray	Light gray	Light gray
Nickel	Dark gray	Off white	Bright silvery white
Lead	White to gray	Light gray and crystalline	White

Figure 63.—Color code for the identification of metals.

APPEARANCE

Examining the outside unfinished surface of a metal is not always sufficient evidence to classify it, but does make it possible to classify the metal into a group, thereby limiting the additional tests needed for classification. The color of the metal will put it into a class. This classification is further broken down by examining the surface. If it shows forging

marks or the evidence of a mold, it is likely low-carbon or cast steel. Or if the outer surface shows rolling or forging marks, the metal may be high-carbon steel. The outer surface of aluminum shows evidence of having been rolled or molded. Stainless steel in the unfinished state is only slightly rough. Wrought iron, copper, brass or bronze, monel metal, and nickel all have smooth outer unfinished surfaces, while lead, although smooth, gives the appearance of being velvety. The iron group, white cast iron, gray cast iron, and malleable iron, will show the evidence of a sand mold in their unfinished state.

If color and appearance are still not sufficient evidence upon which to base your classification, then you should resort to the chip test, or the spark test.

CHIP TEST

The chip test is made by removing a small amount of material from the sample of metal with a sharp cold chisel. The material removed will vary from small broken fragments to a continuous strip. The chip may have smooth sharp edges. It may be coarse-grained or fine-grained. Or it may have sawlike edges where it has been cut. The size of the chip is important in identifying the metal. The ease with which chipping takes place is important in the identification of the sample. This method is another that is largely a result of practice. Try chipping various metals of known kinds. Examine the chips until you are sure you can recognize them the next time you have occasion to see them.

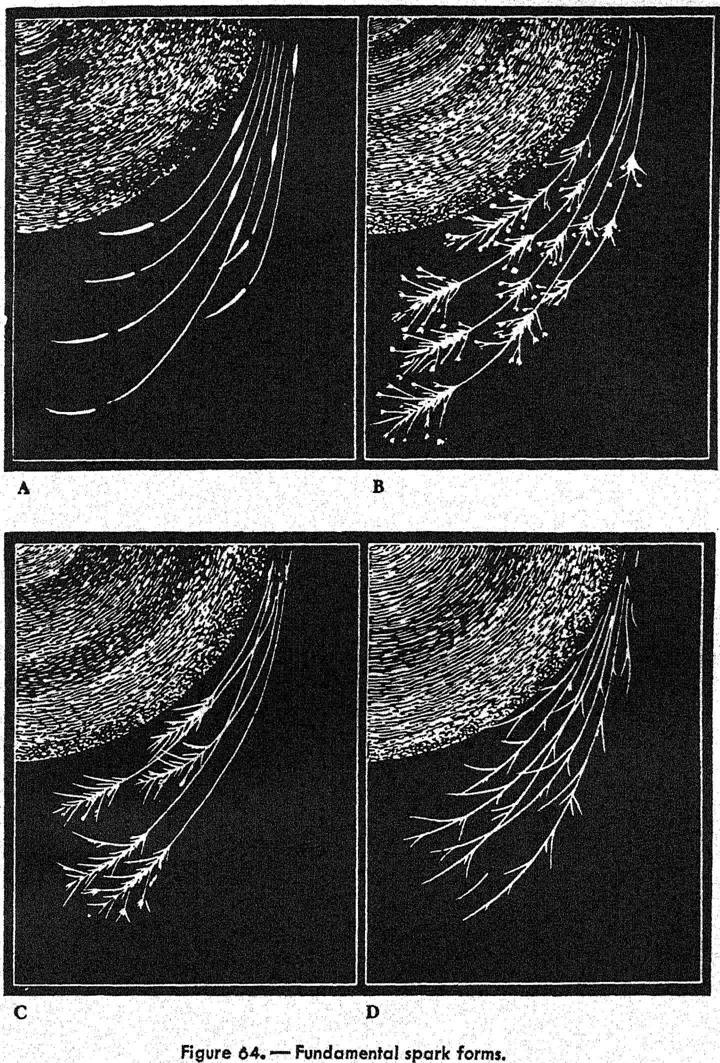
The following information will help you to recognize the more common metals:

1. *White cast iron.*—Chips come off in small fragments. It is brittle, and the chipped surface is not smooth.
2. *Gray cast iron.*—The chips are about ⅛″ in length. It is not easily chipped as the chips break off, preventing a smooth cut.
3. *Malleable iron.*—The chips are not as small as cast iron, being from ¼″ to ⅜″ in length. It is tough and hard to chip.

4. *Wrought iron.*—The chips have a smooth edge and may be continuous if desired. It is soft and easily cut or chipped.
5. *Low-carbon and cast steel.*—The chips have smooth edges and may be continuous if desired. It is easily cut or chipped.
6. *High-carbon steel.*—The chips show fine-grain fracture. Their edges are lighter in color than those of low-carbon steel, and they may be continuous if desired. The metal is hard but can be chipped.
7. *Copper.*—The chips are smooth, have saw edges where cut, and can be continuous where desired. It is easily cut.
8. *Brass and bronze.*—The chips are smooth and have saw edges. It is difficult to obtain a continuous chip. Brass and bronze are easily cut but more brittle than copper.
9. *Aluminum and aluminum alloys.*—The chips are smooth, have saw edges, and can be continuous if desired.
10. *Monel metal.*—The chips have smooth edges, and may be continuous if desired. It chips easily.
11. *Nickel.*—The chips have smooth edges and can be continuous if desired. It chips easily.
12. *Lead.*—Any shape of chip may be obtained because of the softness of the metal. It is soft enough to cut with a knife.

THE SPARK TEST

The spark test is made by holding a sample of the material against a power grinder. The sparks given off, or the lack of sparks, assist in identifying the metal. The length of the spark stream, its color, and the type of sparks are the features for which you should look. There are four fundamental spark forms produced by holding a sample of metal against a power grinder (see figure 64). *A* shows shafts, bud, break, and arrow. The arrow or spearhead is characteristic of molybdenum, a metallic element of the chromium group which resembles iron and is used for forming steel-like alloys with carbon. The swelling or buds in the spark line indicate nickel with molyb-



A B C D

Figure 64. — Fundamental spark forms.

denum. *B* shows shafts and sprigs or sparklers which indicate a high carbon content. *C* shows shafts, forks, and sprigs which

indicate a medium carbon content. *D* shows shafts and forks which indicate a low carbon content.

To make the spark test, hold the piece of metal on the wheel in such a manner as to throw the spark stream about 12 inches at a right angle to your line of vision. You will need to spend a little time to discover at just what pressure you must hold the sample to get a stream of this length without reducing the speed of the grinder. It is important that you do not press too hard because the pressure will increase the temperature of the spark stream and the burst. It will also give the appearance of a higher carbon content than that of the metal actually being tested. After practicing to get the feel of correct pressure on the wheel until you're sure you have it, select a couple of samples of metal with widely varying characteristics; for example, low-

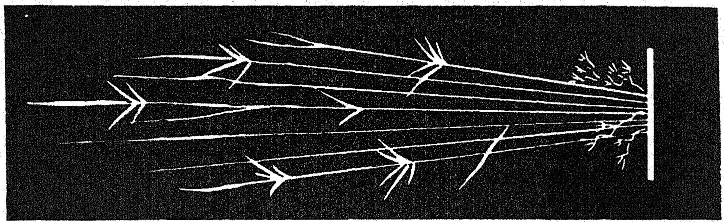


Figure 65.—Sparks produced from low-carbon and cast steel.

carbon steel and high-carbon steel. Hold first one then the other against the wheel, always being careful to strike the same portion of the wheel with each piece. With the eyes focused at a point about one-third of the distance from the tail end of the stream of sparks, watching only those sparks which cross the line of vision, you will find that after a little while you will form a mental image of the individual spark. After you can fix the spark image in mind, you are ready to examine the whole spark picture.

Notice that the spark stream is long (about 70 inches normally) and that the volume is moderately large in low-carbon steel, while in high-carbon steel the stream is shorter (about 55 inches) and large in volume. The few sparklers which may occur at any place in low-carbon steel are forked, while in

high-carbon steel the sparklers are small and repeating and some of the shafts may be forked. Both will produce a white spark stream.

White cast iron produces a spark stream approximately 20 inches in length (see figure 67). The volume of sparks is small with many small and repeating sparklers. The color of the spark stream close to the wheel is red, while the outer end of the stream is straw-colored.

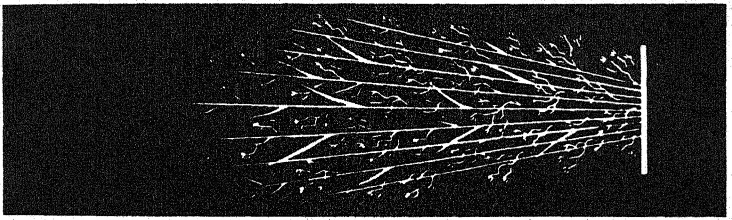


Figure 66.—Sparks produced from high-carbon steel.

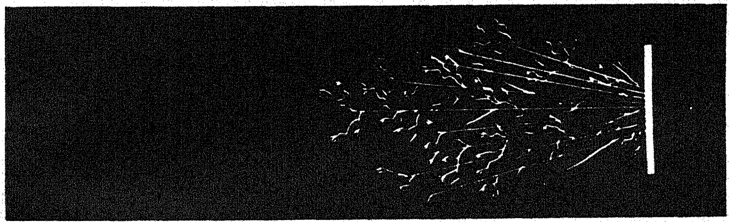


Figure 67.—Sparks produced from white cast iron.

Gray cast iron produces a stream of sparks about 25 inches in length. It is small in volume with fewer sparklers than white cast iron. The sparklers are small and repeating. Part of the stream near the grinding wheel is red, and the outer end of the stream is straw-colored (see figure 68).

The malleable iron spark test will produce a spark stream about 30 inches in length. It is of a moderate volume with many small, repeating sparklers toward the end of the stream. The entire stream is straw-colored.

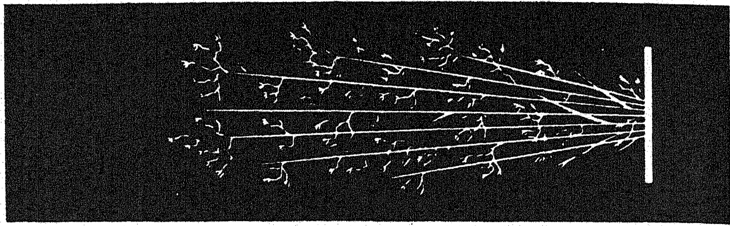


Figure 68.— Sparks produced from gray cast iron.

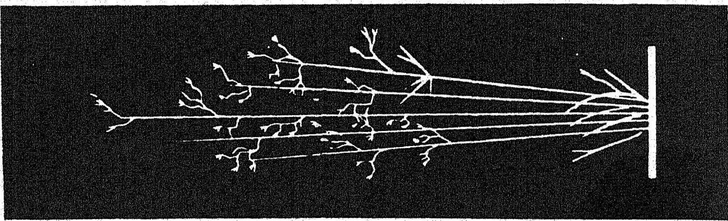


Figure 69.— Sparks produced from malleable iron.

The wrought iron spark test produces a spark stream about 65 inches in length. The stream is of large volume with few sparklers. The sparklers show up toward the end of the stream and are forked. The stream next to the grinding wheel is straw-colored, while the outer end of the stream is a bright red.

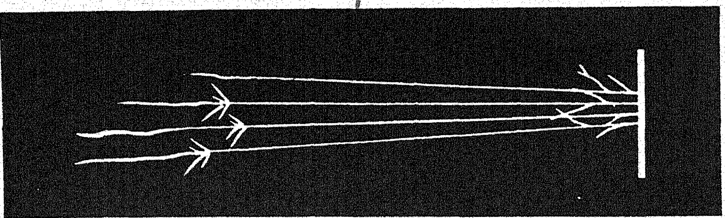


Figure 70.— Sparks produced from wrought iron.

Stainless steel produces a spark stream approximately 50 inches in length of moderate volume with few sparklers. The sparklers are forked. The stream next to the wheel is straw-colored while at the end it is white.

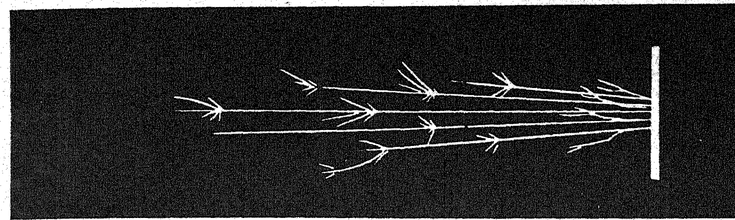


Figure 71.—Sparks produced from stainless steel.

Nickel produces a spark stream only about 10 inches in length. It is small in volume and orange in color. The sparks form wavy streaks with no sparklers.

Figure 72.—Sparks produced from nickel.

Monel metal forms a spark stream almost identical to that of nickel, and must be identified by other means. Copper, brass, bronze, and lead form no sparks on the grinding wheel, but they are easily identified by other means, such as color, appearance, and chip tests.

You will find the spark tests easy and convenient to make. They require no special equipment and are adaptable to most any situation. Here again, experience is the best teacher.

GAS-WELDING TORCH TEST

With the aid of an acetylene gas-welding torch, the Metalsmith can identify the various metals by studying the rate of melting, the appearance of the molten metal and slag, as well as any color changes occurring during heating. When working

metal, study the following reactions and watch for them until you have them well in mind.

White cast iron.— White cast iron melts at a moderate rate and becomes a dull red before melting A medium film of quiet, tough slag develops. The molten metal is fluid, watery, reddish white, and does not show sparks. The depression under the flame disappears when the flame is removed.

Gray cast iron.—The puddle of molten metal is quiet, very fluid, and watery. When the torch flame is raised, the depression in the surface of the metal disappears instantly. A heavy, tough film forms on the surface as it melts. The molten puddle takes time to solidify and gives off no sparks.

Malleable iron.—Malleable iron melts at a moderate rate under the blowpipe and becomes red before melting. A medium film of slag develops which is quiet and tough, but can be broken up. The molten puddle is fluid, watery, and straw-colored. It boils and leaves blowholes. The outside bright steel-like band gives off sparks, but the center does not.

Wrought iron.—Wrought iron melts quietly and rapidly under the blowpipe without sparking. It becomes a bright red before melting. It has a peculiar slag coating, oily or greasy in appearance, with white lines. The molten puddle is liquid and straw-colored. It is quiet and easily broken up. The molten puddle is not viscous and is usually quiet, although it may have a tendency to spark.

Low-carbon and cast steel.—The steel gives off sparks when melted, and solidifies quickly, almost instantly. It melts quickly under the blowpipe and becomes bright red before melting. The slag is similar to the molten metal and is quiet. The molten puddle is liquid, straw-colored, and it sparks.

High-carbon steel.—The molten metal is brighter than in the case of low-carbon steel, and the melting surface has a cellular appearance. It sparks more freely than mild steel, and the sparks are whiter. It melts quickly under the blowpipe and becomes bright red before melting. The slag is similar to the molten metal and is quiet.

Stainless steel.—The action under the flame varies with the alloy.

Copper—Copper melts slowly under the flame and may turn black and then red. The copper color may become intense before melting. There is little slag. The molten puddle has a mirror-like surface directly under the flame and a tendency to bubble. On account of good heat-conducting properties, a larger flame is required to produce fusion of copper than would be needed for a steel piece of the same size. Copper containing small amounts of other metal melts more easily and solidifies more slowly than pure copper.

Brass and bronze.—Brass and bronze melt quite rapidly under the flame and become noticeably red before melting. True brasses contain zinc, which gives off white fumes when the brass is melted. Bronze contains tin. Even a slight amount of tin makes the alloy flow freely like water. Because of a small amount of zinc which is usually present, bronze may fume slightly, but never as much as brass.

Aluminum.—Aluminum and its alloys melt faster than steel with no apparent change in color. The stiff black scum which forms is usually quiet. The molten puddle is the same color as the unheated metal and is fluid. The black scum forming on the surface tends to mix with the metal and is difficult to remove.

Monel metal.—Monel melts more slowly than steel and becomes red before melting. It flows clearly without any sparklers. The slag forms a gray scum in considerable amounts and is quiet and hard to break up. The molten puddle is fluid under the slag and quiet. A heavy black scale is formed on cooling.

Nickel.—Nickel melts more slowly than steel and becomes red before melting. The slag in the form of gray scum is quiet and hard to break up. The molten puddle is fluid under the slag and quiet.

Lead.—Lead melts at a very low temperature with no apparent change in color. The melted metal becomes covered with a thin, dull gray slag coating. The molten metal is white and

fluid under the slag, but may boil if too hot, giving off poisonous fumes. Avoid breathing these fumes.

HARDNESS TESTS

Most metals possess some degree of HARDNESS—that is, the ability to resist penetration by another material. Metals which are considered hard are both solid and firm. They resist scratching or wear.

Figure 73.— Hardness.

Many methods have been evolved for measuring hardness. Each has its particular features and all are frequently used.

They will be taken up in the order of their importance to you. For most practical purposes the FILE HARDNESS TEST will be the one that you will be using. You will find quite frequent reference made to the ROCKWELL and BRINELL hardness numbers in your study of metals and tools. If you have duty with a repair ship or on shore establishments with an organization mainly concerned with inspection of Navy materials or certain supplies, you will have occasion to become familiar with some of the other types of hardness tests. Figure 74 is a table which is used to convert hardness as measured by one method to hardness as measured by another commonly used method.

BRINELL			ROCKWELL			
Dia. in mm. 3000 kg. load 10 mm. ball	Hardness No.	Vickers or Firth Hardness No.	C 150 kg. load 120° Diamond Cone	B 100 kg. load 1/16″ dia. ball	Sclero-scope No.	Tensile Strength 1000 psi.
2.05	898					440
2.10	857					420
2.15	817					401
2.20	780	1150	70		106	384
2.25	745	1050	68		100	368
2.30	712	960	66		95	352
2.35	682	885	64		91	337
2.40	653	820	62		87	324
2.45	627	765	60		84	311
2.50	601	717	58		81	298
2.55	578	675	57		78	287
2.60	555	633	55	120	75	276
2.65	534	598	53	119	72	266
2.70	514	567	52	119	70	256
2.75	495	540	50	117	67	247
2.80	477	515	49	117	65	238
2.85	461	494	47	116	63	229
2.90	444	472	46	115	61	220
2.95	429	454	45	115	59	212
3.00	415	437	44	114	57	204
3.05	401	420	42	113	55	196
3.10	388	404	41	112	54	189
3.15	375	389	40	112	52	182
3.20	363	375	38	110	51	176
3.25	352	363	37	110	49	170
3.30	341	350	36	109	48	165
3.35	331	339	35	109	46	160
3.40	321	327	34	108	45	155
3.45	311	316	33	108	44	150
3.50	302	305	32	107	43	146
3.55	293	296	31	106	42	142
3.60	285	287	30	105	40	138

BRINELL		Vickers or Firth Hardness No.	ROCKWELL		Sclero-scope No.	Tensile Strength 1000 psi.
Dia. in mm. 3000 kg. load 10 mm. ball	Hardness No.		C 150 kg. load 120° Diamond Cone	B 100 kg. load 1/16″ dia. ball		
3.65	277	279	29	104	39	134
3.70	269	270	28	104	38	131
3.75	262	263	26	103	37	128
3.80	255	256	25	102	37	125
3.85	248	248	24	102	36	122
3.90	241	241	23	100	35	119
3.95	235	235	22	99	34	116
4.00	229	229	21	98	33	113
4.05	223	223	20	97	32	110
4.10	217	217	18	96	31	107
4.15	212	212	17	96	31	104
4.20	207	207	16	95	30	101
4.25	202	202	15	94	30	99
4.30	197	197	13	93	29	97
4.35	192	192	12	92	28	95
4.40	187	187	10	91	28	93
4.45	183	183	9	90	27	91
4.50	179	179	8	89	27	89
4.55	174	174	7	88	26	87
4.60	170	170	6	87	26	85
4.65	166	166	4	86	25	83
4.70	163	163	3	85	25	82
4.75	159	159	2	84	24	80
4.80	156	156	1	83	24	78
4.85	153	153		82	23	76
4.90	149	149		81	23	75
4.95	146	146		80	22	74
5.00	143	143		79	22	72
5.05	140	140		78	21	71
5.10	137	137		77	21	70
5.15	134	134		76	21	68
5.20	131	131		74	20	66
5.25	128	128		73	20	65
5.30	126	126		72		64
5.35	124	124		71		63
5.40	121	121		70		62
5.45	118	118		69		61
5.50	116	116		68		60
5.55	114	114		67		59
5.60	112	112		66		58
5.65	109	109		65		56
5.70	107	107		64		56
5.75	105	105		62		54
5.80	103	103		61		53
5.85	101	101		60		52
5.90	99	99		59		51
5.95	97	97		57		50
6.00	95	95		56		49

Figure 74. — Hardness conversion table.

The simplest of all the methods of testing hardness is the FILE HARDNESS TEST. This is also the oldest and most useful of the testing methods. To determine whether or not a metal is hard, you grasp the handle of the file in your right hand, with the index finger extended along the file, and rub the surface to be tested slowly but firmly with the sharp teeth. As soon as you discover whether the file will bite, remove it. The metal to be tested may be held in the left hand and rested on a bench, or held in a vise. The simplicity of this method makes it especially valuable for repeated consecutive tests, such as testing the hardness of teeth on a gear. This test is probably better for testing wearing metals such as gears than for testing cutting tools, since the cutting or abrasion made by the file closely resembles the wear on moving machine parts. It has been found that often a chisel or other cutting tool will give good service although it is soft enough to be cut with a file.

There are three factors that influence comparisons of file hardness. These are:

1. The size, shape, and hardness of the file.
2. The speed, pressure, and angle of the file while making the test.
3. The composition of the metal being tested and the heat-treatment to which it has been put.

A special file made for testing will eliminate in part the error that is involved in file testing. For beginners, a master test block may be used to advantage. That is, try the file on a block of the desired hardness and then, by comparison, you can discover whether the metal to be tested is softer, harder, or just the same as the master test block. At any rate, the file chosen should be uniform and standard. A 10-inch mill bastard file is a good file to use.

The speed, pressure, and angle of the file while making the test is controlled by the skill of the workman. The slower the speed, the more accurate the test. High speeds will wear off both the surface of the file and the part to be tested, thus giving

the false impression of being soft. Light pressure and high speed will wear away the surface faster than heavy pressure and low speed. If your tests are to be of any value, they must be made at the same speed and pressure. A narrow surface will cut faster than a broad surface. It is better to clamp the part to be tested in a vise so you can test with the file at the same angle at all times.

Different metals with the same hardness will file differently. For example, quenched-carbon steel parts, with a Rockwell C-60, cannot be cut with a 10-inch mill bastard file, while chromium steel parts with a Rockwell C-62-64 will often cut easily. (See section on Rockwell hardness testing.) One leading American manufacturer states that his files, made especially for testing, will not cut straight carbon tool steel immediately after drastic quenching, but will cut it after it is tempered to 375°F. although the Rockwell hardness remains the same.

In short, we may say that if the material is cut by the file with extreme ease and tends to clog the spaces between the file teeth, it is VERY SOFT. If the material offers some resistance to the cutting action of the file and tends to clog the file teeth, it is SOFT. If the material offers considerable resistance to the file but can be filed by repeated effort, it is HARD and may or may not have been heat-treated. If the material can be removed by extreme effort and in small quantities by the file teeth, it is VERY HARD and has probably been heat-treated. If the file slides over the material and the file teeth are dulled, the material is EXTREMELY HARD and has been heat-treated.

File testing is an art acquired by experience. It is not a scientific method. The greatest objection to the use of the file test is that no accurate records can be kept. But it can be used very successfully, especially when no other instrument is suitable or available; for example, for testing the hardness of the inside of holes, bottoms of grooves, and on oddly shaped pieces that are inaccessable to machines. The skilled Metalsmith who uses a file for testing soon learns to allow for the factors that might influence the test, and finds the file test an extremely useful measure of hardness. The required skill is not difficult to acquire.

ROCKWELL HARDNESS TEST

Of all hardness tests the Rockwell probably gets most frequent mention. Its principle is one of measuring the indentation in a piece of metal made by a ball or cone of a given size under a given pressure. A 120° diamond cone is used to make impressions in the harder metals and a $\frac{1}{16}$-inch steel ball is used for the softer metals. A dead weight, acting through a series of levers, is used to press the cone or ball into the surface of the metal to be tested. Then the depth of penetration is measured. The softer the metal is the deeper the impression will be under a given load. The average depth of penetration on the softest steel is only about .008 of an inch. The hardness is indicated on a dial indicating the Rockwell B and the Rockwell C hardness scales. The harder the metal the higher the Rockwell number will be. For testing hard steels, the diamond point should be used and should be read on the C scale. For nonferrous metals the B ball is used and read on the B scale. Figure 75 shows the Rockwell tester and the numbers in the figure correspond to those following to show how it is used.

1. Place the piece to be tested on the testing table. The testing table is also called the anvil.
2. Turn the wheel elevating the testing table until the piece to be tested comes in contact with the testing cone or ball. Continue to turn until the penetrator grips the sample.
3. Turn the retaining flange on the dial face of the gauge to set the dial zero behind the pointer.
4. Push the handle back an inch to release the weights and apply the major load, which is 150 kg. for hard metals tested with diamond cone. Weights of 100 kg. are used for testing softer metals with the steel ball.
5. Pull the handle forward, thereby removing the major but not the minor load. This will leave the ball in contact with the specimen but not under pressure.
6. Observe where the moving pointer comes to rest.
7. Read the ROCKWELL HARDNESS number on the dial.

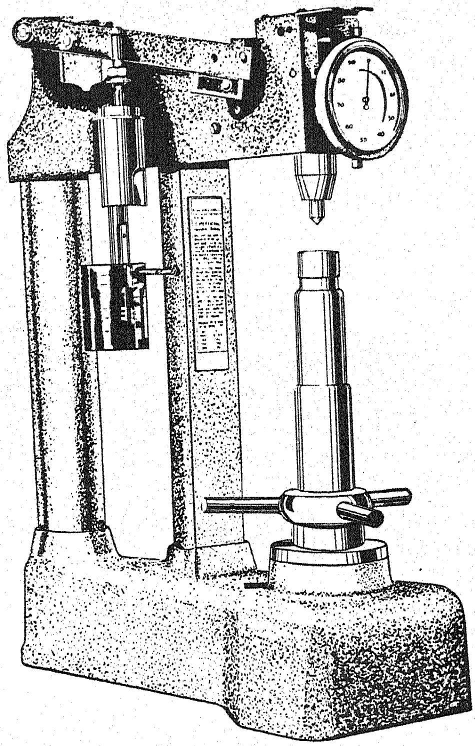


Figure 75. — The Rockwell tester.

BRINELL HARDNESS TEST

Where the Brinell hardness testing machine (see figure 76) can be used, it furnishes a convenient and reliable hardness test. It is not suitable for thin or small pieces. The measure of hardness is determined by the resistance it offers to the penetration of a steel ball under pressure. The Brinell hardness number is

found by measuring the distance the ball is forced into the piece tested under a given pressure. The greater the distance, the softer the metal and the lower the Brinell number will be. The width of the indentation is measured with a microscope and the hardness number corresponding with this width is found by consulting a standard chart. This machine is most valuable for testing soft and medium-hard metals and for testing large pieces. On hard steel the imprint of the ball is so small that it is difficult to read.

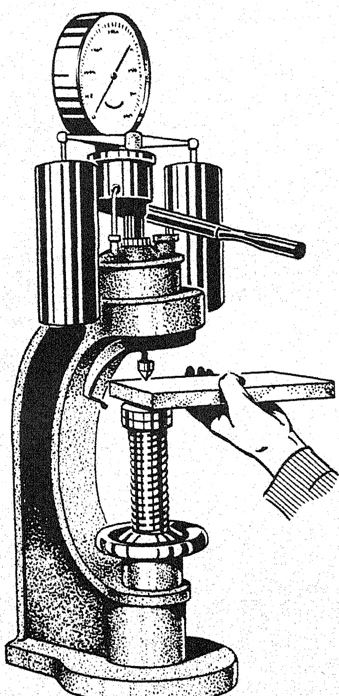


Figure 76.—The Brinell hardness testing machine.

THE SCLEROSCOPE HARDNESS TEST

If you were to place a mattress on the deck and drop two rubber balls from the same height, one on the mattress and one on the deck, the one dropped on the deck would bounce higher. This is because the deck is the harder of the two surfaces. Now this is the principle upon which the Scleroscope works. In the Scleroscope hardness test a diamond-pointed hammer is dropped through a guiding glass tube onto the test piece and the rebound (bounce) is checked on a scale. The harder the metal being tested, the higher the hammer will rebound and the higher will be the number on the scale. The Scleroscope is portable and can be used to test the hardness of pieces too big to be placed on the anvil or tables of other machines. Since it is portable and can be held in the hand, it may be used to test the hardness of large guns, and of marine and other forgings that cannot be mounted on stationary machines. Another advantage of the Scleroscope is that it can be used without doing damage to finished surfaces. The main disadvantage of this machine is its inaccuracy. The accuracy of the Scleroscope depends upon the following factors:

1. Small pieces do not have the necessary backing and cannot be held rigidly enough to give accurate readings.
2. If large sections are not rigid, if they are oddly shaped, if they have overhanging sections, or if they are hollow, the readings may be in error.
3. If oil-hardened parts are tested, oil may creep up the glass tube and interfere with the drop of the diamond-pointed hammer in the instrument, thus causing error.

THE MONOTRON HARDNESS TEST

The Monotron Hardness Tester works on the same principle as the Rockwell and Brinell machines. You probably won't be using this test as it is not commonly used aboard ship. However, as a Metalsmith you will find it of interest to know something of all tests used in connection with metals. Essentially, it consists of a diamond cone or a steel ball. This ball is forced into the metal by a static load. The main difference between

this and other machines is that the hardness of a metal is determined by the amount of pressure required to force the cone or ball to a given depth. This feature makes this machine valuable for testing materials other than metals. It serves to eliminate errors involved in other methods caused by confusion of elastic recovery. Elastic recovery is that property of metal which causes it to return to its original shape after being bent, compressed, or stretched.

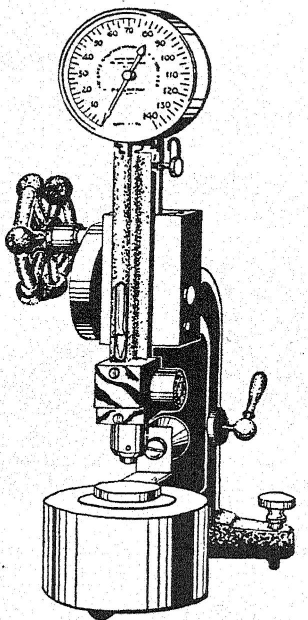


Figure 77.—The Scleroscope hardness testing machine.

In other words, in tests where it is necessary to read the width or depth of penetration in a metal, this reading may not be accurate because metal, being more or less elastic, tends to return to the original shape, thus changing the depth and width of the penetration.

THE VICKERS DIAMOND PYRAMID HARDNESS TEST

The principles involved in testing hardness with the Vickers Diamond Pyramid and the Brinell testing machines are almost identical. The difference lies in the fact that the indenter of the Vickers machine is a diamond accurately cut and polished to the shape of a square-based pyramid, which makes it accurate for testing thin sheets as well as the hardest steels. The disadvan-

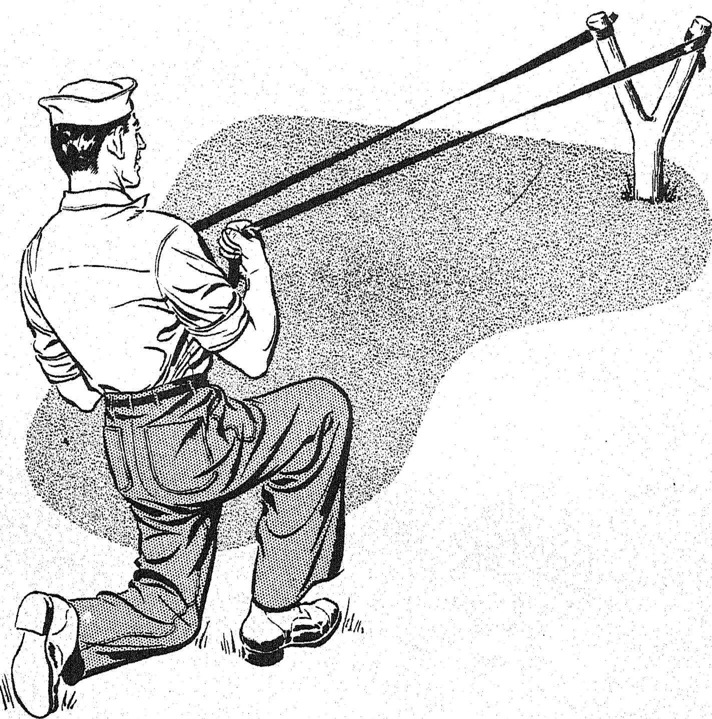


Figure 78.— Elasticity.

tage of this machine is that it must be operated with care, because it is a machine of precision. Also, the surfaces to be tested must be prepared very carefully. This, like the Monotron hardness test, is one of the less common hardness tests.

THE MICROCHARACTER HARDNESS TEST

The Microcharacter test is used for testing areas of metals so small (no larger than one square inch) that it can be done only with the aid of a microscope. It is also used for testing thin layers of metal. The instrument was originally designed for studying bearing alloys; but now it is generally used by skilled metallurgists, mainly for research. The principle is the measurement of a cut of microscopic dimension made in the metal by a diamond finely ground to the shape of a solid right angle or of the corner of a cube.

PHYSICAL TESTING OF METALS

The physical tests discussed in the following pages are used to test the quality of metal, including weld metal. They may also be used to check the skill of the welder. These tests may be described as destructive tests because the test specimens must be loaded until they fail before the desired information can be gained. For welds, the tensile test is the oldest and most commonly used. But the bend tests reveal the most valuable information as to the properties and quality of the welded joint.

Other methods of testing, in which the piece tested is not destroyed, include X-ray, gamma-ray, electrical resistance, magna-flux, hydrostatic, and acid-etch tests.

TENSILE TESTS

Tensile strength may be defined as resistance to longitudinal stress or pull, or as stress in pounds per square inch of cross-sectional area.

Tensile tests are made to determine the tensile strength of a given specimen of metal. Figure 80 shows a tension test specimen which has been tested. The specimen shown is composed entirely of alloy steel weld metal and has been machined round for the test. Before breaking in a typical "cup" and "cone" fracture, the specimen "necked" or drew down and stretched or elongated considerably. This indicates a good specimen.

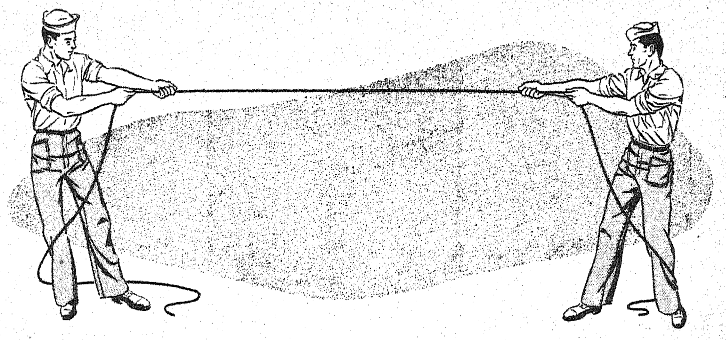


Figure 79.—Tensile strength.

Tensile tests are also used to test the strength of welds. A sample or specimen like the one in figure 81 is cut from a welded section of plate or other material for making this test.

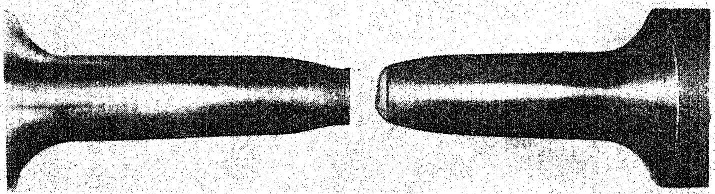


Figure 80.—Tension test specimen which has parted.

Most of your welded construction aboard ship must have certain tensile strength. The usual procedure for determining tensile strength is to insert the specimen between the jaws of a pull test machine like the one in figure 82, and increase the pull (tension) gradually until the metal breaks, the width and the thickness of the specimen having been measured before testing. The machine indicates the load or pull in pounds at the point

of breaking. To find the tensile strength of the specimen, first determine its cross sectional area in square inches. Then—

$$\frac{\textit{Tensile Load}}{\textit{Area}} = \text{Tensile Strength expressed in pounds per square inch.}$$

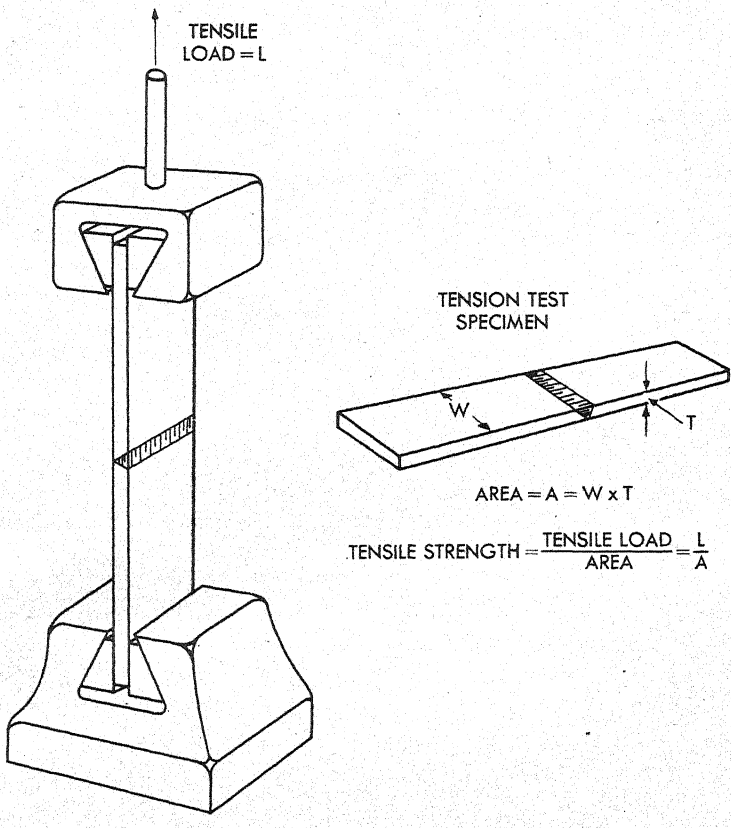


Figure 81.— Tension test of welded metal.

In addition to the portable-type testing machine, the Navy uses on some shore stations a stationary-type tensile testing machine. The portable machine operates on the hydraulic

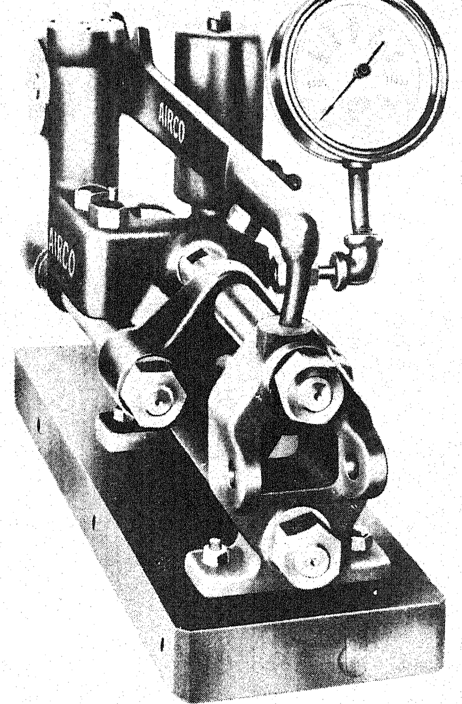


Figure 82.— Airco portable tensile and bend testing machine.

principle and is capable of bending as well as pulling the specimens. As the specimen is being tested, the load in pounds is registered on a gauge located on one side of the portable-type machine. In the stationary-type machine, the load applied to the test specimen is registered on a balancing beam. In either case, the load at the point of breaking is recorded.

The usual requirement for tensile test of welds is that the weld must test not less than 90 percent of the tensile strength of the base metal.

You will be hearing the term TENSILE STRENGTH often, but it isn't difficult. Just remember that tensile strength is that property of the metal which resists pulling forces that would tend to

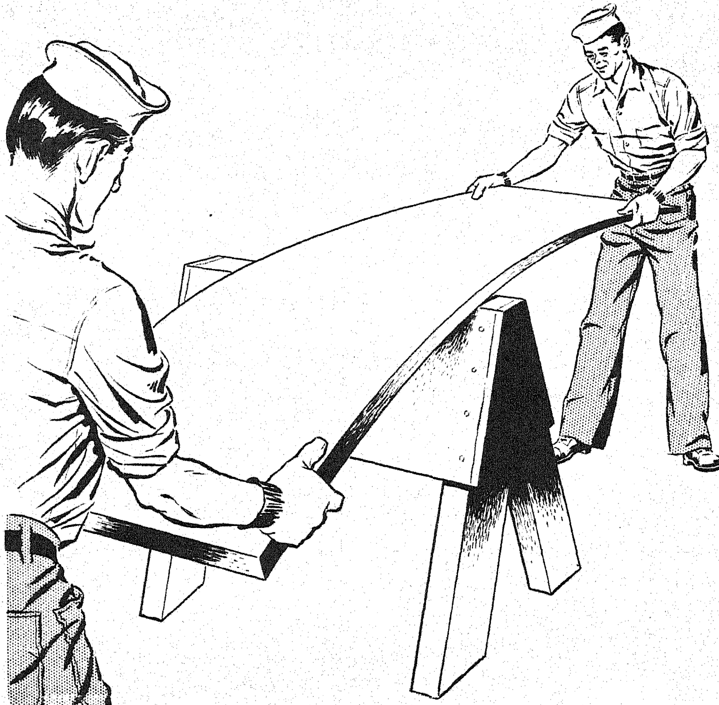


Figure 83.—Bending strength.

pull the metal apart, and TENSILE TESTS are the measurement of that force.

BEND TESTS

Bend tests, used for measuring the various qualities of welds, are of several kinds; free bend, back bend, and guided bend.

The FREE BEND TEST has been devised to measure the ductility of the weld metal deposited in a welded joint. (Ductility is that property of a metal which makes it capable of being drawn out or hammered thin, see figure 91.) The test is very simple to perform and may be done with the tools at hand in any shop. Take a test specimen like the one in figure 84. Grind the top of the weld flush with the surface of the base metal. On the face

scribe a line $\frac{1}{16}$ inch in from each edge of the weld. Measure the distance between the lines in inches to the nearest .01 inch. Let the resulting figure equal X.

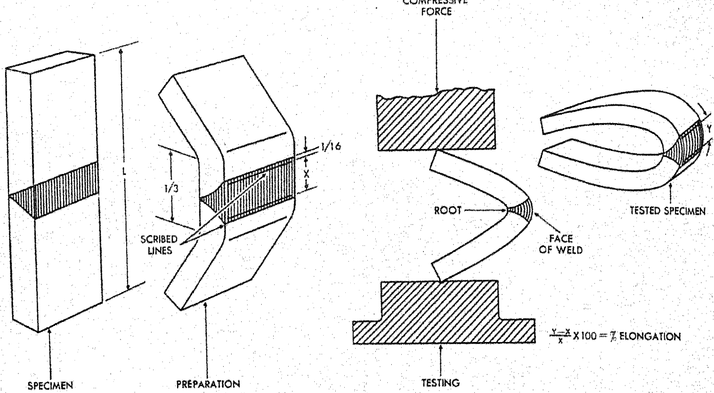


Figure 84.— Free bend test.

Prepare the specimen for test as shown in figure 85 by bending the piece slightly one-third of its length from either end. Now you are ready to place the piece in a machine or vise and continue the test. Pieces $\frac{1}{4}$ inch in thickness or less may be tested in a vise. Exert compressive force on the specimen until a crack or cracks greater than $\frac{1}{16}$ inch appear. If no cracks appear, continue to bend until the specimen is bent to 180° and flattened. After testing, the distance between the scribed lines is again measured on the specimen with a flexible rule. (See the fourth step in the illustration in figure 84.) Call this last measurement Y. Now you have the necessary data to figure the percent of elongation. Here is your method.

$$\frac{Y - X}{X} \text{ x } 100 = \% \text{ of elongation}$$

The requirements for this test are that the minimum elongation be 15 percent and that no cracks greater than 1/16 inch exist on the face of the weld.

The BACK BEND TEST is used to determine the quality of the weld metal and the degree of penetration into the root of the V of the welded joint. The specimens used are similar to those required for the free bend test, except that they are bent with the root of the weld on the tension side (OUTSIDE) of the bend. The specimens tested are required to bend 90° without breaking apart. The back bend test, as well as the free bend test, is being largely replaced by the guided bend test.

The GUIDED BEND TEST is used to determine the quality of weld metal at the face and root of a welded joint, as well as the degree of penetration and fusion into the base metal. These tests are made in a jig. The test specimen is placed across the supports of the die. A plunger, operated from above by hydraulic pressure, forces the specimen into the die. To fulfill the requirement of this test, the specimen must bend to the capacity of the jig or 180 degrees. No cracks should appear on the surface greater than ⅛ inch. The face bend tests are made in this jig with the face of the weld in tension (outside). The root bend tests are made with the root of the weld in tension (outside) as shown in figure 85.

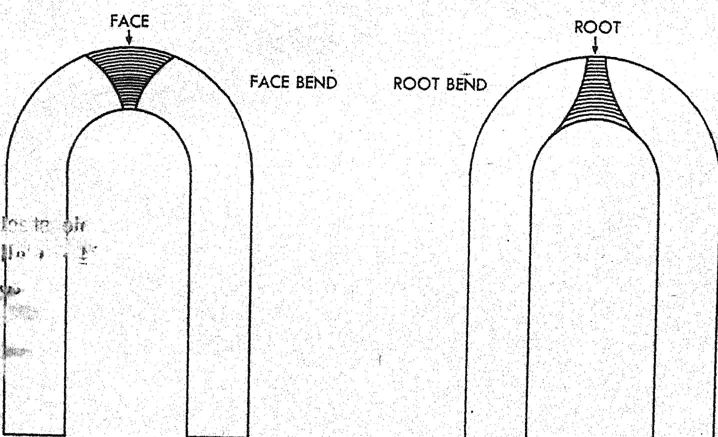


Figure 85.—Guided bend test specimens.

Figure 86 shows a machine used for making the guided bend test. Many of these machines are used in welding schools and testing laboratories for the daily testing of specimens.

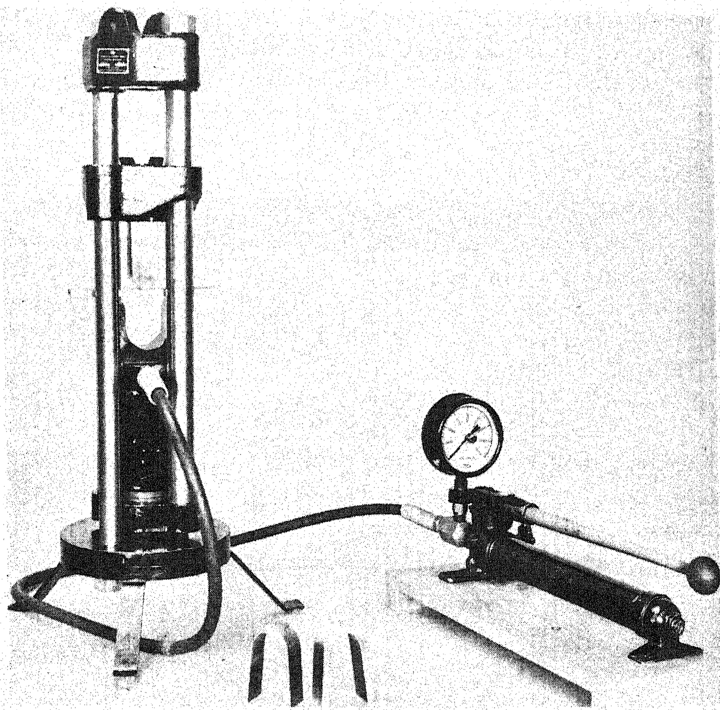


Figure 86.—Testing machine for making guided bend tests.

This machine is simple in construction and easy to use. It works by hydraulic pressure and can apply a direct load up to 40,000 pounds, and even more on small specimens. When making the test, place the specimen in position in the machine as previously indicated and pump the lever of the pump. Keep your eye on the large gauge and watch the load grow. You will know the actual load under which the test piece fails by the position of an auxiliary hand which is carried along by the gauge pointer. The hand remains at the point of maximum load after the pointer returns to zero.

Another test used for welds and weld metals is the NICK-BREAK test. It is used to determine the soundness and ductility of weld metal, although less frequently than the guided bend test. It reveals slag inclusions, gas pockets, lack of fusion, or other internal defects in weld metal.

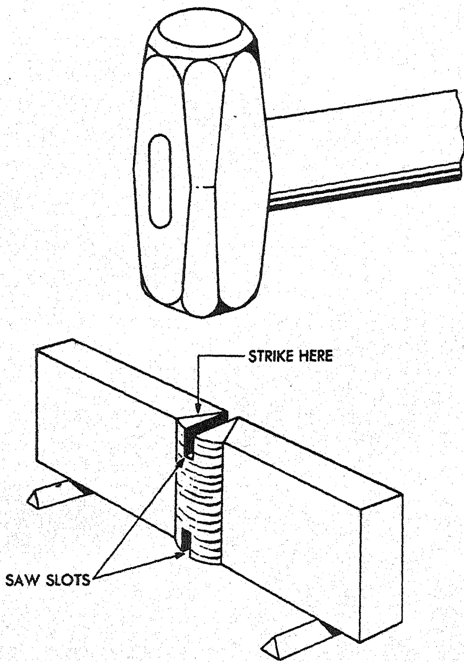


Figure 87.—Nick-break test.

The specimen is made from a welded joint either by machining or cutting with an oxyacetylene torch. Each edge of the weld is slotted with a saw. The piece thus prepared is placed on two steel blocks and is struck with a hammer (see figure 87). After repeated hammering, the weld between the slots will break, exposing the interior of the weld metal. The exposed metal should be completely fused and free from slag inclusions.

The size of any gas pocket must not be greater than 1/16 inch across the greatest dimension. There should not be more than six gas pockets per square inch of weld surface.

THE X-RAY TEST

The X-ray test is used to find internal defects in welds without destroying the weld. This test is used primarily as a check on the welder's skill, and is not ordinarily made by the Metalsmith. Such defects as cracks, slag inclusions, blowholes, and places where the metal did not fuse may be found by this test. This method of testing is applied to such welds as those made in the hull of a submarine. The method consists of placing an X-ray tube on one side of the plate and a photographic film on the other. An exposure ranging from a few seconds to fifteen minutes is used, depending upon the thickness of the plate being examined and the power of the tube. When the film is developed, the defects show up as black spots or bands. This method is the best of the nondestructive tests for welds. Figure 88 is an X-ray of a butt-welded joint, showing porosity and poor root penetration.

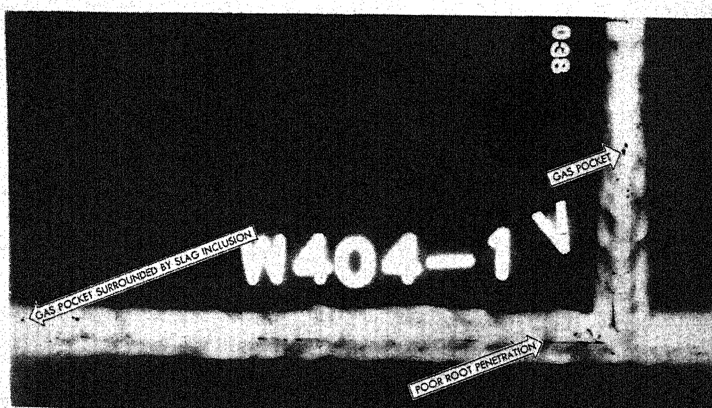


Figure 88.—X-ray test.

OTHER NONDESTRUCTIVE WELD TESTS

The GAMMA-RAY TESTS are made by the same principle as the X-ray, the difference being that the gamma rays come from a particle of radium instead of an X-ray tube. Heavy plate welds may be tested by this method, but it takes considerably longer than with X-ray. Operators using either the X-ray or gamma ray apparatus must be thoroughly familiar with the properties of X-rays and radium.

The ELECTRICAL RESISTANCE TEST is used on small welds and small welded sections. The resistance to the flow of electric current is affected by slag or other foreign matter included in the weld. The current-carrying capacity for pure metal is compared with that of the weld metal for a similar test piece. The relative changes in the electric current-carrying capacities of the weld metal are used as a measure of its quality.

The MAGNA-FLUX TEST is a method used to find hair-like cracks on the surface of welds or plate. It may also be used to show defects below the surface to the depth of ½ inch. The test piece is magnetized so that the magnetic field lies across the direction of the defects. A fine magnetic powder is then sprinkled on the surface. The magnetic field set up is interrupted by the defects causing north and south poles which attract the powder and make the outline of the defects visible.

The HYDROSTATIC TEST is used to check the quality of welds on a closed vessel such as a tank. It is made by filling the tank with water and applying pressure. Any drop in pressure or the appearance of leakage at the joints indicates a faulty weld.

The ACID-ETCH TEST is used to find fine cracks at the bottom of chipped-out areas in castings or welds. The acid reacts on the edges of cracks in the metal and thus makes them visible.

TESTING FOR OTHER PROPERTIES

In addition to the tests previously mentioned in this chapter there are many other properties of metals which can be tested. Some of the more common of these tests are the fatigue tests, compression tests, cupping tests, and shear tests. It is sufficient to mention here only the purpose of these tests since they are

used by the more advanced metal workers. Your contact with these tests will be in terms of quality of tools and materials.

Have you ever bent a piece of sheet metal back and forth until it broke? Its breaking was a result of FATIGUE. FATIGUE TESTS measure the amount of bending back and forth that is necessary to bring a piece of metal to the breaking point without actually breaking it. Technically stated, the resistance of metallic materials to large numbers of repetitions of stress is known as fatigue.

Figure 89.— Compression.

COMPRESSION TESTS are used for testing bearing metals, for determining the general compressive strength of metals, and as

a measure of the elasticity of metals. Compressive strength is that property of the metal which resists forces which tend to squeeze the metal together. This test is the reverse of the tensile strength test.

The Navy uses the SINGLE BLOW IMPACT TEST to measure shock-resistance. This test is similar to the nick-break test for welds except that a machine with a heavy pendulum is used instead of a hammer. These machines will be found only on shore stations and in testing laboratories.

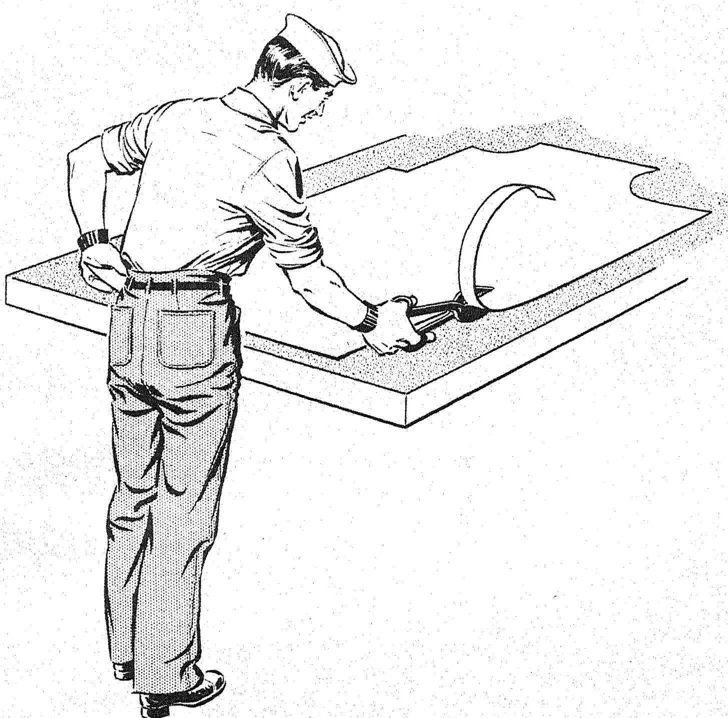


Figure 90. — Shear strength.

SHEAR TESTS are used to measure shear strength. Shear strength is figured from the amount of pressure required to force a disc from the specimen with the use of a punch and die. Or

it may be defined as that property of the metal which resists forces which tend to cut it in the manner of a pair of shears. Rivets are subjected to shear tension.

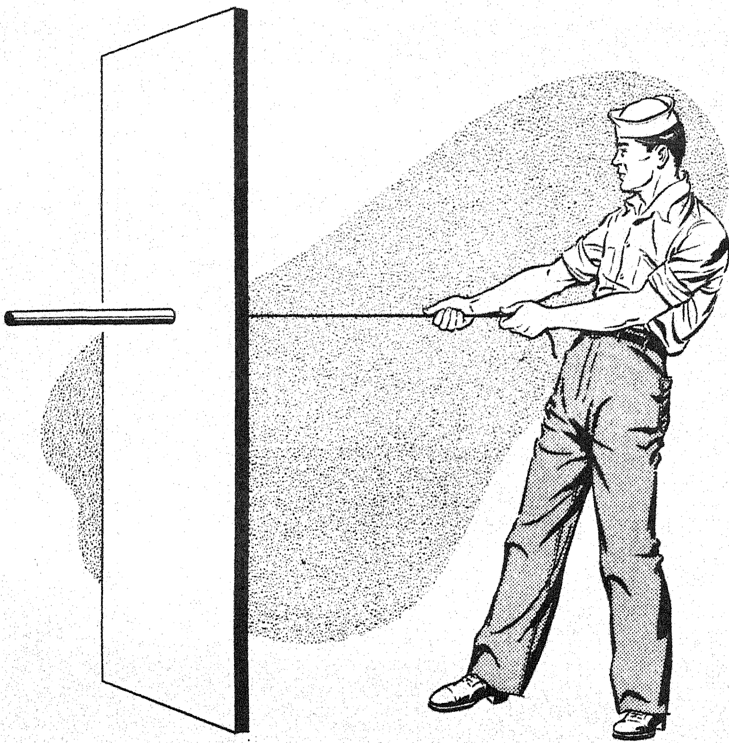


Figure 91. — Ductility.

CUPPING TESTS are used as an index or measurement of ductility or drawability in sheet metal. Test specimens are usually in the shape of squares, discs, or strips, and are of the same thickness as the sheet metal they represent. Although cupping tests have been used for many years, no generally accepted standards of tests have been agreed upon. Therefore the results of this test are of little more than general information value to you.

Of course, you will not use all of these test every time you go into the shop to do a job, but you will be using some of them quite often. You have the knowledge that it takes to make many of these tests, and for most of them no special tools are needed. Use your senses, use your knowledge, and use your tools, and you will find that you won't ever get caught with a counterfeit article.

QUIZ

Complete the following statements (do not write in this book).

1. The five tests devised for the identification of metals are (1) ________, (2) ________, (3) ________, (4) ________, (5) ________.
2. The features for which you would look in making a spark test are the length of the ________ ________, its ________, and the type of ________.
3. In accomplishing a spark test, excessive pressure will increase the temperature of the spark stream and the burst, and give the appearance of a higher ________ content and a different metal from that actually being tested.
4. There are ________ fundamental spark forms possible, depending upon the type of metal being tested.
5. Items to study when using a welding torch to identify metal is the ________ of melting, the ________ of the molten metal and slag, as well as any color changes occuring during heating.
6. Under the welding torch test, white cast iron melts at a moderate rate and becomes ________ ________ in color before melting.
7. When torch testing malleable iron a ________ film of slag develops which is quiet and tough.
8. Wrought iron melts quietly and rapidly under the torch blowpipe without ________.
9. When doing the file hardness test, ________ pressure and ________ speed will wear away the surface faster than ________ pressure and ________ speed.
10. If file hardness tests are to be of any value they must be made at the same ________ and ________.
11. The Brinell Hardness Testing machine is most valuable for testing ________ and medium hard metals.
12. The main disadvantage of the Scleroscope Hardness Tester is its ________.

13. A piece of metal has a width of 4 inches and a thickness of .625 inches and has been submitted to a tensile load of 80,000 pounds. The tensile strength will be ______ pounds per square inch.

14. When performing a tensile test on a round alloy steel weld metal, an indication of good ductility is that before breaking it will ______.

15. A metal's resistance to longitudinal stress or pull is referred to as its ______ strength.

16. To fulfill the requirements of the Guided Bend Test the specimen must bend ______ degrees.

17. A test which measures the amount of bending back and forth that is necessary to bring a piece of metal to the breaking point without actually breaking it is called the ______ Test.

Select the one best answer to each of the following statements.

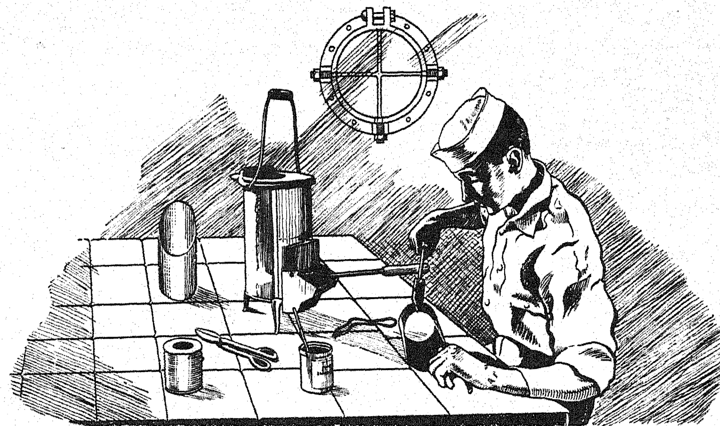
18. If a metal chips off in small fragments, is brittle, and the chipped surface is not smooth, it is identified as—
    (*a*) Low-carbon steel.
    (*b*) Malleable iron.
    (*c*) Wrought iron.
    (*d*) White cast iron.

19. The spark test is made by—
    (*a*) Striking together two metals of different metallic content.
    (*b*) Producing a spark gap with electricity.
    (*c*) Holding the metal against a power grinder.
    (*d*) Placing metal in a lathe and applying a cutting stone.

20. When spark testing low- and high-carbon steel, the color of the spark stream will be—
    (*a*) White.
    (*b*) Bright red.
    (*c*) Straw.
    (*d*) Orange.

21. The test in which metal is subjected to a gradual load or pull increase until the metal breaks is the—
    (*a*) Compression test.
    (*b*) Impact test.
    (*c*) Tensile test.
    (*d*) Shear test.

22. A test used to find internal defects in welds without destroying the weld is the—
    (*a*) Nick-Break Test.
    (*b*) X-Ray Test.
    (*c*) Vickers Diamond Pyramid Test.
    (*d*) Guided Bend Test.



CHAPTER 6

SOLDERING WITH SOFT SOLDERS

Man has been doing soldering for many centuries. The process has remained fundamentally the same, but a few improvements in methods and tools have lightened the work considerably. The greatest improvement has been in heating methods. In medieval times the only source of heat was charcoal and the bellows. Later, coke and the forced draft were introduced. Later still, such modern heating methods as the gasoline blowtorch, automatic alcohol torch, blowpipe, gas oven, and the electric soldering copper were introduced. The most modern methods and tools are discussed here.

Soldering is the simplest of the joining processes. It is a process of joining cast or fabricated metals at low temperature. This means the fastening together of two like or unlike metals by using another metal entirely different from one or both of the base metals without melting either one. Solders are used for joining iron, nickel, lead, tin, copper, zinc, and many of their alloys. Glass or porcelain may even be joined by soldering, provided their surfaces have first been coated with metal by spraying or some other method.

Solders are classified as soft or hard. Soft solders differ from

hard solders (brazing solders and silver solders) in that the former are alloys that are fusible (capable of being melted) at temperatures below 700°F.

One of the differences between the soldering process and the welding process is that in soldering, the metals to be joined are not heated to the melting point, whereas in welding they are heated to this point or above it. Therefore the melting point of solder must be lower than that of the metals to be joined. Soft solders are of low strength and are easily applied because of their low melting point.

Solder is an alloy of two metals: lead and tin. Lead melts at 621°F. Tin melts at 465°F. But tin-lead (50/50 solder) melts at 450°F., a lower temperature than the melting temperature of either tin or lead. This half-and-half solder is the most effective for use in sheet metal work. Solder containing 60 percent tin and 40 percent lead has a still lower melting point, 390°F. For this reason it is especially well-suited for work on light gage metal. The lower the temperature at which a solder can be worked, the less likely one is to heat the metal to a point that would cause rapid expansion, known as heat buckling.

Solders are classified according to their tin content as COMMON, MEDIUM, and FINE. Common solder has the least percent of tin, and fine solder the greatest percent of tin. Common solder has the highest melting point and is cheaper. For that reason it is used most frequently in plumbing work and for splicing the covering of lead cables. Fine and medium solders have lower melting points and are used for electrical work.

Commercial bar solder is identified by numbers giving the percentages of tin and lead. The first number is the percentage of tin contained in the alloy; for example, 30/70 indicates that the bar of solder is made up of 30 percent tin and 70 percent lead. Alloy designated 50/50 is called half-and-half and is sometimes labeled that way. It is preferred for most sheet metal jobs. A 30/70 alloy is in common use, however, because it is cheaper.

Scientists have discovered that molten solder sticks to the surface of the base metal by means of molecular attraction. A very strong bond is formed because of the friendliness of the

molecules of the solder for the molecules of the base metal. This molecular attraction is known as ADHERENCE.

For such jobs as securing electrical connections, joining sheet metal where great strength is not required, or making water-tight riveted or lap-joint sheet metal containers, soldering is the answer. In combat zones where simplicity, speed, and make-shifts are essential, you will be breaking out the soldering gear frequently.

THE ABC'S OF SOLDERING

For good soldering, the following rules must be observed:

A surface must be clean of all grease, oxides, and other foreign matter.

B sure to heat the surface to be soldered to a temperature just hot enough to melt the solder, and use a flux which will melt at temperatures below the melting point of the solder so that it will not form pits or cavities in the soldered joint.

C that all traces of corrosive fluxes have been removed after the joints have been made.

PREPARATION

The first step in the preparation of surfaces to be soldered is cleaning. The strength of the joint depends on the adherence of the solder to the metal to be joined. To secure good adherence, the surface of the metal and of the solder must be free of oxide, grease, dirt, and other foreign substance. All metals are normally covered with oxides which increase as the metal is heated to the soldering temperature. Remember—if the solder is to adhere to the metal, the metal must be well-cleaned. Cleaning may be done mechanically or chemically.

In mechanical cleaning the surfaces are scraped, filed, or rubbed with sandpaper or emery paper. If a power buffer or emery wheel is available, it may be used effectively. Cleaning of tough jobs on repair work is made easier by warming the area to be repaired almost to the temperature required to melt the solder. After the metal is heated with a torch, it is a good

idea to rub the surface with a wire brush, sandpaper, or steel wool to remove oxide that may have formed during the heating process.

Surfaces are usually cleaned with chemicals. Cleaning by chemical action with pickling solutions of acid is known as fluxing. Ordinarily, pastes or solutions that contain zinc chloride are used for soft soldering. The material holding the flux is evaporated by the heat of the soldering operation, leaving a film of the flux on the work. At the soldering temperature, as the molten solder is applied, the flux melts and dissolves the oxides from the solder and the work. As the process is completed, a thin film is formed, protecting the work from further oxidation. A complete discussion of fluxes is presented later in this chapter.

Frequently, metal parts to be soldered have a coat of tin. If this is not the case, you may find it easier to solder by applying a coat of pure tin or solder metal to the surfaces of the metal parts to be joined. This process is called tinning. Use the same method described later in this chapter for tinning a soldering copper.

METHODS OF APPLICATION

Most common metals and their alloys can be readily soldered. Several factors are involved in determining the method of soldering to be used. These include character of metals to be soldered, their position, size of the parts to be joined, speed with which job must be completed, and the shape, tensile strength, and appearance required of the finished job. Surfaces to be soldered must always be heated to the melting point of the solder to be used.

Different methods for heating these surfaces are:

1. By the wiping method.
2. By use of a soldering copper.
3. By use of a blowtorch.
4. By solder bath.
5. By sweating.

WIPING METHODS

The wiping method of soldering is used for joining sections of lead pipe; joining lead pipe with brass, bronze, or copper fittings; and joining lead covered electrical cables using a lead sleeve.

The steps in soldering by the wiping method are as follows:

1. Heat the solder until it is in a semiliquid state.
2. Hold cloth or wiping pad under the joint to be soldered.
3. Pour solder slowly over the joint, catching overflow on cloth.
4. Press the hot solder caught on cloth against the joint and work until smooth.
5. Continue to pour and work until sufficient heat is applied to form the joint properly.
6. Allow to cool slowly, wiping off excess solder and shaping joint.

Your first attempts at wiping may not turn out well, but remember that skill is attained by practice. This particular method requires considerable skill but you will find it convenient for soldering in places too tight for a soldering copper.

If joints are large, repeated pouring may be necessary to attain proper heat.

Stearin (stearic acid) in stick form is sometimes used for fluxing when wiping joints. Wiping solders usually contain about 30 percent tin and 70 percent lead, and you have a range of about 140° in which to work them.

USE OF A SOLDERING COPPER

A soldering copper is sometimes called a soldering iron. It consists of a forged piece of copper connected by an iron rod to a handle. The copper end is called the head or bit. There are several types of soldering coppers, but the most frequently used are the pointed copper, the stub copper, and the bottom copper. The pointed copper is used for general soldering work. The stub copper is used for flat seams requiring considerable heat. The bottom copper is used for soldering seams of pails, pans,

trays, and other tough-spot jobs. Electric soldering coppers are built with internal heating coils. The heads are removable and interchangeable, thus allowing the use of various shaped tips. Electric coppers may be used for light work and are especially good for work on electrical connections.

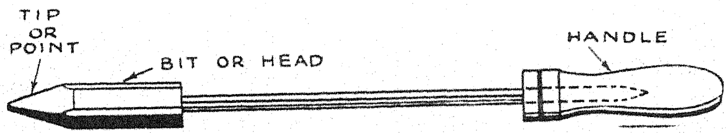


Figure 92.— Soldering copper.

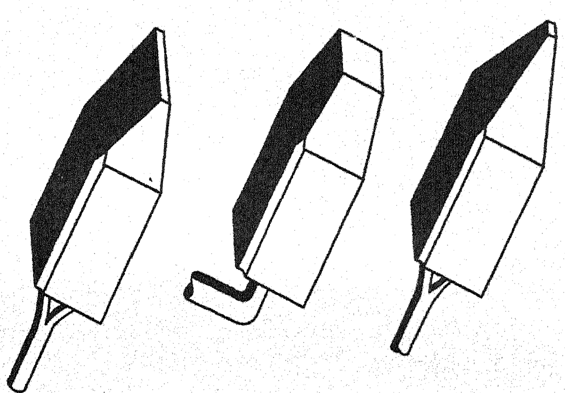


Figure 93.— Soldering coppers.

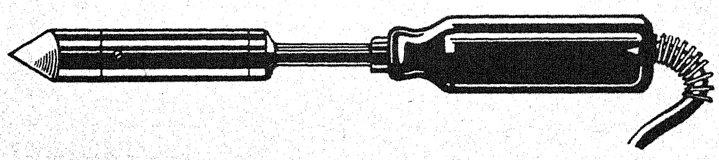


Figure 94.— Electric soldering copper.

Both wood and fiber handles are available for soldering coppers. The standard wood handle is forced on the rod. Some fiber handles are screwed on. Two coppers are used while soldering. One is heated while the other is being used. Their sizes are determined by the weight in pounds for two copper ends. Thus a pair of 2-pound (2-lb.) coppers means that each weighs 1 pound. The common sizes are 1-lb., 1½-lb., 2-lb., 3-lb., 4-lb., and 6-lb. per pair.

It is not desirable to use a light copper for heavy gage metal since it will not hold enough heat to heat the metal properly or allow the solder to flow. Neither should heavy coppers be used for light gage metal as they are awkward to use and result in poor work. Also, there is the danger of excess heat causing the metal to buckle.

Before starting a soldering job see that your copper is properly filed and tinned (coated with solder). Follow these directions for filing and tinning a soldering copper, and you will find it an easy job.

1. Heat the copper to be tinned until it is cherry red.
2. Clamp the copper in a vise as shown in figure 95.
3. Using a 12-inch single-cut bastard file, bear down on the forward stroke and release pressure on the return stroke—DON'T ROCK THE FILE.
4. File the tapered sides of the copper until they are bright and smooth—KEEP HANDS OFF THE HOT COPPER.
5. Smooth off sharp edges and point.
6. Reheat sufficiently to melt solder.
7. Rub each filed side back and forth across a cake of sal ammoniac, adding a little solder to the copper until it is coated (tinned).

Powdered rosin placed on a brick may be used instead of the cake of sal ammoniac. The same method is used. This method for tinning is used when sal ammoniac is not available or when rosin is to be used as a flux on tin plate.

Every time a copper is overheated it must be retinned. The soldering copper is filed to remove burnt substances from it and to keep it smooth. This must be done often. If the soldering

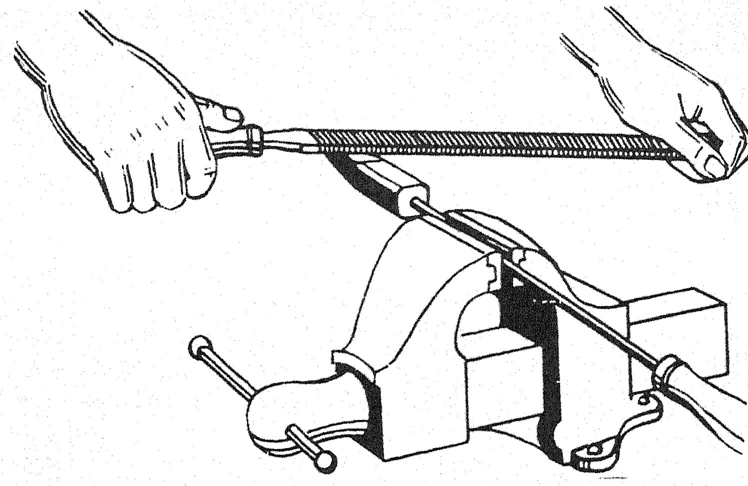


Figure 95.—Filing a copper.

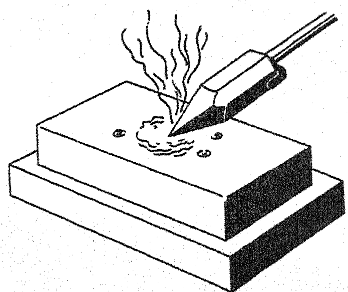


Figure 96.—Tinning with sal ammoniac.

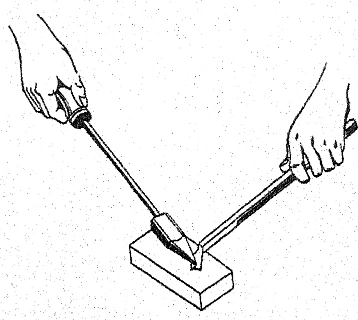


Figure 97.—Tinning with rosin.

copper becomes too blunt or if it is not the correct shape for the job to be done, it must be forged and filed. Here are instructions for forging a soldering copper.

1. Heat the copper to a bright red.
2. File until burnt tinning and pits are removed.
3. Reheat copper to bright red.
4. Holding the copper on an anvil, forge it to the required shape by striking it with a large hammer (see figure 98). The point should be blunt and the head should not be tapered too much or the end of the copper will cool too rapidly. Hammer the point back as the forging progresses. Turn the copper often to produce a square surface. Reheat as often as necessary.
5. Reheat to bright red and take as many of the hollows out of it as possible with a flat-faced hammer.
6. File and tin.

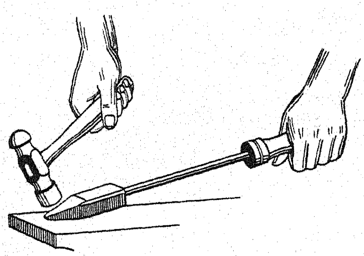


Figure 98.—Forging a soldering copper.

A pair of soldering coppers will last a long time if they are not overheated and if cleaned just before soldering. To clean, wipe the point on a damp rag, clean the point on sal ammoniac, or dip the point in a dip-cup. Any container containing a dipping solution is called a dip-cup.

A dipping solution for cleaning a soldering copper may be made by dissolving a small amount of powdered sal ammoniac in water. Soldering salts dissolved in water may also be used as a dipping solution. Never use as a dipping solution the acid or flux that is used for the soldering process. Your copper will color the flux and stain the job. Now that you have the prin-

ciple well in mind, follow these rules, and you will turn out a top-notch job.

1. Select the proper pair of soldering coppers, observing size, and shape. File and tin ,according to previous instructions.
2. Heat the copper. Do not allow it to become red hot as this burns the tinning and oxidizes the copper, requiring retinning. Keep one copper heating while the other is in use.
3. Select the proper flux. See the discussion of fluxes later in this chapter.
4. Place the job to be soldered in the proper position on a suitable support.
5. Apply the flux with swab or brush—one or two strokes is sufficient.
6. Clean the soldering copper by dipping the tinned surface in dipping solution or by wiping off the tip with a damp cloth.
7. Pick up solder with the copper (see figure 99).
8. Hold the copper at one end of the seam until heat from the copper penetrates through the metal. The metal must absorb enough heat from the copper to melt the solder or the solder will not stick.
9. If the job is a seam, tack it together at enough places to hold the pieces in position (see figure 100).
10. Start at one end of the seam and hold the copper with a tapered side of the head flat along the seam until the solder starts to flow freely into the seam.
11. Draw the copper with a slow, steady motion toward you along the seam, and add as much solder as necessary without raising the soldering copper from the work.
12. Heat the copper as often as necessary, but remember that the best job can be done if the seam can be started and finished without lifting the copper from the surface to be soldered, and without retracing completed work.
13. If raw or killed acid is used as a flux, wipe the excess acid off the seam with a clean damp cloth.
14. Allow the seam to cool and the solder to set before moving the job.

When soldering a grooved seam, tacking is not necessary, as the seam is held together by the lock. Nor is it necessary to tack a riveted seam. But for a watertight job the rivets must be soldered. To solder a square, rectangular, or cylindrical bottom, first make solder beads (sometimes called shots) by

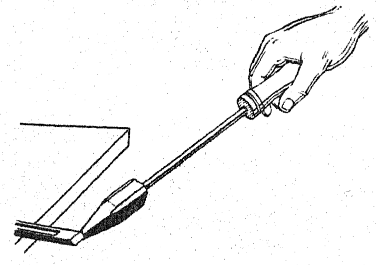


Figure 99.— Picking up solder.

holding solder against a hot copper and allowing the beads to drop on the bench. (See figure 102.) Flux the seam and drop one of the cold beads of solder in the bottom of the container. Heat, clean, and dip the soldering copper and place it in the bottom as shown in figure 103. Hold the soldering copper in a stationary position until the solder starts to flow freely into the seam. Draw the copper slowly along the seam, rolling the job on the edge of the bottom at the same time. Add more beads as needed and reheat the copper when necessary.

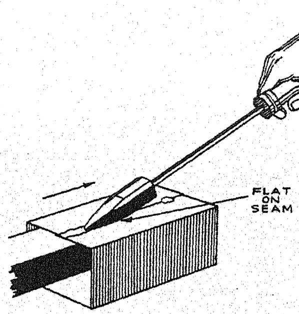


Figure 100.— Soldering a seam.

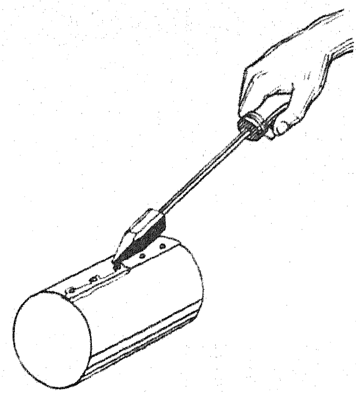


Figure 101. — Soldering around rivets.

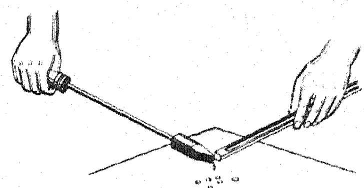


Figure 102. — Making solder beads.

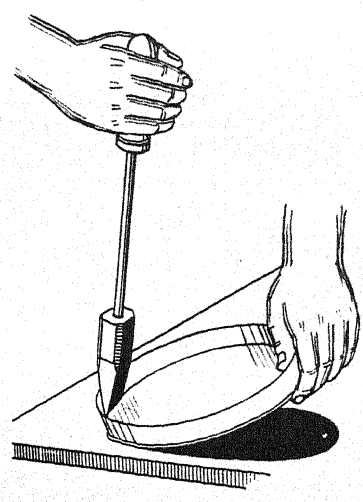


Figure 103. — Soldering a bottom.

USE OF A BLOWTORCH

On some jobs, surfaces are not flat or in position for use of a soldering copper. On others, the metals to be joined are not large enough in diameter or rigid enough to permit the wiping method. If the wiping method or the use of a soldering copper is not practicable, soldering may be done by playing the flames of a blowtorch directly on the surfaces and then applying the solder cold in bar or wire form. The heated surfaces melt the solder and excess solder is removed by wiping before the solder has had time to harden completely. This method is most frequently used for soldering wire joints and sweating-on lugs.

The gasoline blowtorch pictured in figure 104 is most commonly used in soldering. Its operation is simple.

Fill the tank about two-thirds full of clean, unleaded gasoline. Unleaded gasoline contains no tetraethyl lead. Pump until sufficient pressure is built up in the tank to cause the gasoline to

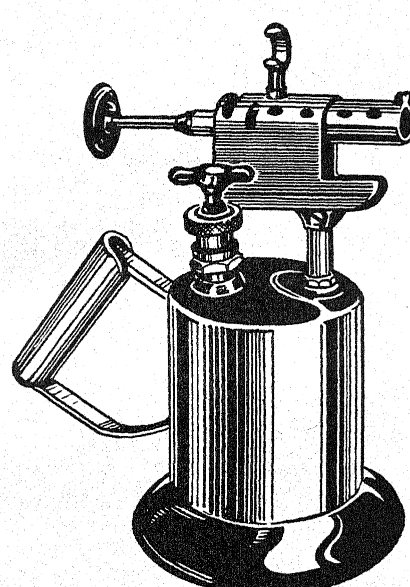


Figure 104.— Gasoline blowtorch.

flow when the valve is opened. Don't pump too tight. Excessive pressure may rupture the torch bottom.

With the valve open, liquid gasoline will flow from the jet of the torch and drip into the priming pan. When the pan is about three-fourths full, close the valve and light off the gasoline with a match. The flame from this burning gasoline heats the perforated nozzle (heating tube). Most of the trouble you will have in lighting and in using torches will be caused by insufficient heating before opening the valve to start the torch. Give it time and keep it out of a draft and you'll get better results. When the nozzle is hot, open the valve slowly, allowing the gasoline vapor which has been formed to flow from the nozzle. It will burn with an almost colorless flame and with considerable force. By working the valve, you can adjust this flame to any desired intensity. Adjust to produce a clean, pale blue flame for best results. When heating a soldering copper, the flame will show green when the copper has reached proper temperature for soldering work. If the pressure decreases, it is permissible to pump the torch while it is operating. To secure, close the valve sufficiently tight to prevent gas from escaping. Don't close the valve too tightly. Remember the metal is hot and will contract when it cools, causing the valve to stick.

There is very little maintenance to the gasoline torch providing you use ONLY CLEAN, CLEAR, UNLEADED GASOLINE. If you use leaded gasoline, a compound will form that will stop up the gasoline passages. The torch will be a source of trouble from then on, as it is almost impossible to clean these passages completely.

For direct flame soldering on small jobs use a GAS BLOWPIPE or an ALCOHOL TORCH. They are designed for the job. The gas blowpipe is an attachment similar to the one used for welding but smaller. It operates on the same principle. Two tubes—one furnishing either natural or manufactured gas, and the other supplying compressed air or oxygen—run together to form the blowpipe.

The automatic alcohol torch works on the same principle as the blowpipe. It is a self-contained unit and creates its own pressure. The tank is filled about two-thirds full with alcohol

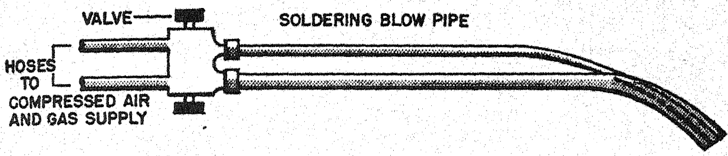


Figure 105.—Blowpipe.

and sealed. To operate the torch, remove the cap and light the wick. The flame from the wick heats the jet tube, causing the liquid alcohol in the container to vaporize and expand. The expansion forces the alcohol vapor from the jet opening where it is ignited to form a hot, light blue flame.

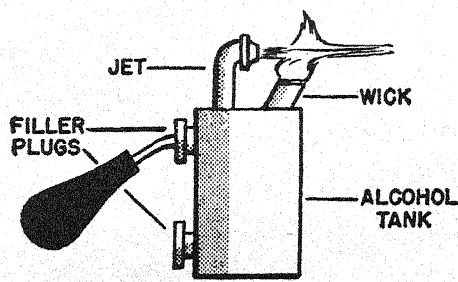


Figure 106.—The automatic alcohol torch.

Another heating device commonly used is a gas oven. If you have access to one, you will use it to heat your soldering coppers. These ovens have one, two, or three burners, on which heat is hand-controlled by means of valves.

The gas oven, sometimes called a gas furnace, is the best device for heating soldering coppers. A refractory lining that resembles cement protects the metal part of the furnace from being burned, and reflects the heat over the soldering coppers. Thus it is possible to produce a temperature of 1800°F. which is more than is needed to heat 10-pound soldering coppers. Some ovens are provided with a pilot light which is allowed to continue to burn during the working period. To secure, turn off pilot light valves and main valves. Check the valves before and

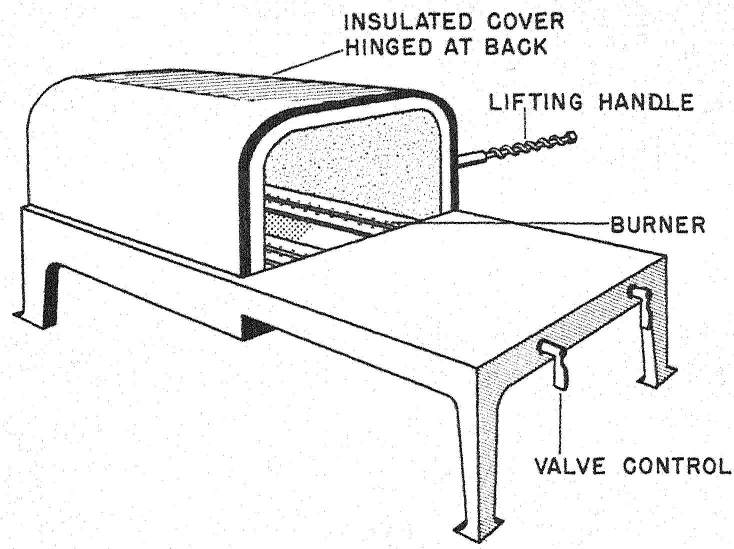


Figure 107.— Gas oven.

after using, to avoid accumulations of gas and resulting danger of explosion.

THE SOLDER BATH

In some instances, where parts are too small or too numerous to be soldered by one of the previously mentioned methods, the parts are joined by means of dipping in molten solder.

For making the solder bath, solder may be obtained in slabs weighing from 15 to 35 pounds. These slabs are usually 50/50 or 40/60 tin-lead (40 percent tin and 60 percent lead).

SOLDERING BY SWEATING

In electrical work sweating is the best method for securing a terminal lug to a cable. To sweat a lug on a cable, clean and tin the end of the cable. Flux the terminal lug and fill it with molten solder. Insert the cable in the lug. Hold fast in place, giving ample time for the solder to cool and set.

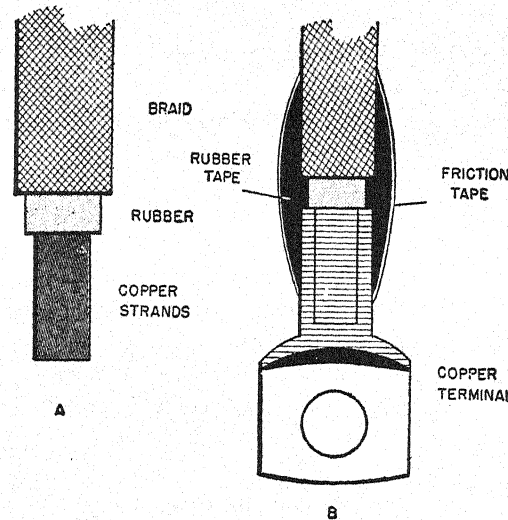


Figure 108.—Sweating terminal lug on cable.

WORKING HEAT

Molten solder should never be raised much beyond necessary working temperature. If the soldering job is big, you'll need a lot of heat to raise the temperature of the metal sufficiently to receive the solder. It is better to use a large amount of solder at about the usual soldering temperature than to raise the temperature of the solder.

As the temperature of molten solder is increased, the rate of oxidation is increased. When molten solder is overheated in the air, more tin than lead is lost. If, however, it is necessary to heat a pot of solder excessively—for example, when the solder has to be carried a long distance from the place where it is heated to the place where it is used—be sure to protect the exposed surface with a hard soldering flux such as that made of powdered borax, charcoal, and soda. Never stir nor skim overheated solder. This causes excessive loss by oxidation.

A soldering flux is a material which will remove the oxide film already present and protect the surface of both metal and solder while they are being heated to the soldering temperature.

The strength of a soldered joint depends on the adherence of the solder to the metal being joined. To secure good adherence it is necessary that the surface of the metal and of the solder be free from dirt, grease, and oxides. Familiar examples of oxide on metals are rust on iron, corrosion on copper, and the white film visible on aluminum that has been exposed to the atmosphere for some time.

Fluxes are of two classes: corrosive and noncorrosive. The corrosive fluxes eat away the soldered metals unless they are thoroughly washed off after soldering. The fluxes ordinarily used for soft soldering are solutions or pastes that contain zinc chloride. Zinc chloride and sal ammoniac are corrosive fluxes. The solvent or other medium holding the flux material is evaporated by the heat of the soldering operation, leaving an unbroken layer of the solid flux on the work. At the soldering temperature, the solid flux is melted and partially decomposed with the liberation of hydrochloric acid. This acid then dissolves the oxides from the surfaces of the solder and the work. The melted flux also forms on the work a protective film that prevents further oxidation from taking place.

Corrosive fluxes should not be used in electrical work, [illegible] there is a possibility of some [illegible] the joint [illegible] eventually breaking the circuit by [illegible] conductor. These fluxes also lower the insulation resistance of the circuits and increase electrical leakage, since all types of corrosive fluxes are excellent conductors. Because zinc chloride and sal ammoniac exhibit corrosive action, it is sometimes necessary to use a noncorrosive flux. ROSIN is the most commonly used flux of this type. Rosin is the amber-co[illegible] chemical compound that remains after turpentine has been removed from the sap of certain pine trees. Rosin is used as a flux when soldering tin plate and lead. It does not clean [illegible] surface of the work, but it does prevent oxidation during

soldering by covering the surface with a protective film. Rosin may be obtained in powdered, liquid, or paste form. Some core solders contain rosin. Core solder is a small tube made of solder which contains flux in the center. Core solder is obtained on spools.

In choosing fluxes, attention should be given to the kinds of metal to be joined and to their massiveness. It takes more heat to solder iron or steel than to solder lead. When a soldering copper is used, the metal is heated in one spot and the heat may be conducted away rapidly. The iron therefore must be exceptionally hot unless the job has been preheated. In such a case the use of rosin is unsatisfactory since this material carbonizes or chars at high temperature, preventing rather than aiding soldering. When you are soldering large pieces of metal together, it's a good idea to pre-tin the parts to be soldered before assembling them. Use the same method that you use to tin a soldering copper. This makes soldering easier and makes joints stronger. Sometimes it's best to preheat the job. Some experts recommend that cast iron be treated with a cold pickling bath of 5 percent hydrofluoric acid before it is soldered. Use hydrofluoric acid with care as it is very corrosive, attacking the flesh and forming painful sores which heal slowly. The vapor is extremely dangerous if inhaled. This acid must be kept in a wax or lead container as it will eat away glass or most metals.

Muriatic acid (also called raw acid) is the commercial form of hydrochloric acid and is yellow in color. This raw acid may be [illegible] a flux [illegible] galvanized iron, but it is a good [illegible] "CUT" the acid by adding scraps of zinc. After the zinc has dissolved, the acid may be weakened to the correct strength by pouring it into an equal amount of water. This forms zinc chloride. Here is what happens: The acid dissolves the zinc, forming zinc chloride and releasing hydrogen gas. When the reaction stops, the solution should be strained. Remember that the fumes are injurious when inhaled. They are inflammable, and will cause metal to corrode. Zinc chloride should be prepared in the open or near openings to the outside. Keep it in closed glass containers away from machines and tools.

Sal ammoniac, another of the corrosive fluxes, is muriate of ammonia, or ammonium chloride. It can be obtained in a highly refined state in crystal form practically free from metallic impurities, and also in one pound brick form under such trade names as Salamac and Speco. When a hot copper is placed in contact with sal ammoniac, the copper is cleaned by the chemical, thus enabling solder to adhere to the copper.

The usual fluxes for common metals are:

METAL	FLUX
Brass, copper, tin	Rosin
Lead	Tallow, Rosin
Iron, steel	Borax, Sal Ammoniac
Galvanized Iron	Zinc Chloride
Zinc	Zinc Chloride
Aluminum	Stearine, special flux

Stearic acid or stearine may be used in soldering aluminum. But a special aluminum solder is now available which makes the use of flux unnecessary.

DON'T DO IT

Don't overheat your soldering copper. It will shorten its life.

Don't dip your soldering copper into soldering flux. It will stain your work.

Don't forget to use a separate dipping solution. It is essential to good work.

Don't leave soldering tools adrift. You might start a fire.

Don't drive handles on soldering coppers by bumping against an anvil. Handles split easily.

Don't inhale fumes from zinc chloride. They're injurious.

Don't leave acid in open containers. The fumes are corrosive.

Don't spill raw acid on your clothes or body. It will attack them.

Don't treat gasoline carelessly. Its dangerous.

QUIZ

Select the one best answer to each of the following statements.

1. With reference to the metals to be joined, the melting point of solder—
   (*a*) Must be higher.
   (*b*) Must be lower.
   (*c*) Should be the same.
   (*d*) Is not an important factor.

2. The melting point of 50/50 solder is approximately—
   (*a*) 200° F.
   (*b*) 400° F.
   (*c*) 600° F.
   (*d*) 700° F.

3. The materials used in soft solder is an alloy composition of—
   (*a*) Copper-tin.
   (*b*) Copper-zinc.
   (*c*) Silver-copper.
   (*d*) Tin-lead.

4. Molten solder sticks to the surface of the base metal to which it is applied by means of—
   (*a*) Gravitational connection.
   (*b*) Magnetic attraction.
   (*c*) Molecular attraction.
   (*d*) Atomic infiltration.

5. The first step in the preparation of surfaces to be soldered is—
   (*a*) Sweating.
   (*b*) Heating.
   (*c*) Tinning.
   (*d*) Cleaning.

6. The most common method of cleaning surfaces to be soldered is by the use of—
   (*a*) Abrasive papers.
   (*b*) Chemicals.
   (*c*) Scrapers.
   (*d*) Steel brushes.

7. When a surface is cleaned with solutions of acid, it is called—
   (*a*) Tinning.
   (*b*) Sweating.
   (*c*) Pickling.
   (*d*) Fluxing.

8. To make soldering easier, a thin coating of molten solder is sometimes applied to a surface. This is called—
   (*a*) Tinning.
   (*b*) Sweating.
   (*c*) Fluxing.
   (*d*) Cleaning.

9. If we wished to request a pair of soldering coppers from stock which weighed 3 pounds each, we would ask for—
   (*a*) Triple 0.
   (*b*) 2-3 lb.
   (*c*) 3 lb.
   (*d*) 6 lb.

10. When preparing to file and tin a soldering copper it should first be heated—
   (*a*) To a dull red color.
   (*b*) To a cherry red color.
   (*c*) To 700° F.
   (*d*) To the melting point of solder.

11. When sal ammoniac is not available for use in the tinning of a copper, a flux which may be used in its place is—
   (*a*) Borax.
   (*b*) Stearine.
   (*c*) Zinc chloride.
   (*d*) Rosin.

12. If a soldering copper becomes overheated it must be—
   (*a*) Retinned.
   (*b*) Forged.
   (*c*) Dipped.
   (*d*) Reheated in a gas furnace.

13. Soldering coppers sometimes do not have the correct shape or may be too blunt for the job which is to be done. If this is the case, they must be—
   (*a*) Recast.
   (*b*) Forged and filed.
   (*c*) Drawn.
   (*d*) Filed and tinned.

14. A small amount of powdered sal ammoniac dissolved in approximately a pint of water can be used on a soldering copper as a solution for—
   (*a*) Fluxing.
   (*b*) Cleaning.
   (*c*) Tinning.
   (*d*) Neutralizing.

15. Riveted seams are soldered to—
   (*a*) Strengthen the joint.
   (*b*) Provide a fillet for appearance.
   (*c*) Make them watertight.
   (*d*) Aid in setting the rivets.

16. The joining of wire and the sweating on of lugs is most frequently accomplished by the soldering method of—
   (*a*) Wiping.
   (*b*) Solder bath.
   (*c*) Spraying.
   (*d*) Sweating.

17. The tank of a blowtorch should be filled to an approximate level of—
   (*a*) 1/3.
   (*b*) ½.
   (*c*) 2/3.
   (*d*) Full.

18. The valve of a blowtorch is most likely to stick when shut off because—
   (*a*) Lead gets on the needle valve.
   (*b*) Metal expands as it cools.
   (*c*) Metal contracts as it cools.
   (*d*) Metal gets rough as it cools.

19. The best source for direct flame soldering on small jobs would be a—
   (*a*) Hauck burner.
   (*b*) Gas blowpipe.
   (*c*) Gasoline blowtorch.
   (*d*) Gas furnace.

20. A pressure pump on an automatic alcohol torch is unnecessary because the heat from the wick causes the liquid in the container to—
   (*a*) Solidify and contract.
   (*b*) Ignite upon contact with the working surface.
   (*c*) Evacuate by syphon force.
   (*d*) Vaporize and expand.

21. The best device for heating soldering coppers is the—
   (*a*) Gas furnace.
   (*b*) Electric element.
   (*c*) Acetylene torch.
   (*d*) Alcohol torch.

22. Pieces which are too small or too numerous to be soldered any other way are joined by dipping in molten solder. This method is called—
   (*a*) Sweating.
   (*b*) Gas furnace.
   (*c*) Solder bath.
   (*d*) Wiping.

23. When the cleaned and tinned end of an electrical cable is inserted in a fluxed terminal lug filled with molten solder, the method is called—
   (*a*) Solder bath.
   (*b*) Sweating.
   (*c*) Wiping.
   (*d*) Tinning.

24. The film removed from the surface of a metal is known as—
   (*a*) Nitride.
   (*b*) Cyanide.
   (*c*) Zinc chloride.
   (*d*) Oxide.

25. The best type of flux to use on electrical work would be—
   (*a*) Rosin.
   (*b*) Zinc chloride.
   (*c*) Stearine.
   (*d*) Borax.

Complete the following statements (do not write in this book).

26. It is always necessary to heat the surface to be soldered to the _____ _____ of the solder to be used.

27. In filing a copper, the pressure should be applied on the _____ stroke and released on the _____ stroke.

28. For best results after starting to solder a seam, one should not lift the copper from the surface until _____ and should not retrace completed work.

29. When working on the seam of a cylindrical bottom, the method of applying solder is to drop a cold _____ in the bottom of the container.

30. Examples of oxides on metals would be _____ on iron and _____ found on copper.

In list *A* will be found the various fluxes used on the different metals given in list *B*. Match items in column A with column B.

A	*B*
(*a*) Borax.	31. Aluminum.
(*b*) Rosin.	32. Brass.
(*c*) Sal ammoniac.	33. Copper.
(*d*) Stearine.	34. Galvanized iron.
(*e*) Tallow.	35. Iron.
(*f*) Zinc chloride.	36. Lead.
	37. Steel.
	38. Tin.
	39. Zinc.

CHAPTER 7

BRAZING AND RELATED JOINING METHODS

Brazing is a term of very ancient origin. It comes from the word "brassing", which is the ancient art of joining brass or copper parts by means of brazing alloys. Today we refer to brazing as a method of joining metals together, without fusion, by means of a molten alloy which has a melting point above 800° F. The melting point of a brazing alloy, like that of a soldering alloy, must be below the melting point of the metals being joined.

Except for the higher temperatures required, brazing is much the same as soft soldering. In fact, brazing is sometimes called hard soldering. The brazed joint is far better and much stronger than the soft-soldered joint. It can also stand much higher temperatures.

Brazed joints are almost as strong as welded joints. They are even preferred for many joints in cast iron, non-ferrous metals, tool steel, and malleable iron. Another advantage in brazing is that the heat required to make a joint is not sufficient to cause serious damage to the properties of the metals to be

joined. This is a big advantage when you are working with alloy steels and tool steels, or with any other metal which has been heat-treated.

FILLERS FOR BRAZING

Three general types of filler alloy are used in the brazing process: SILVER ALLOY, BRASS, and BRONZE. These are broad classifications made on the basis of the melting point of the alloys. Any brazing alloy that you use must melt at a point lower than that of the metals to be joined. Brazing temperatures are always more than 1000° F., however, and any joining operation performed at a lower temperature is properly termed soldering. Silver brazing alloys are commonly referred to as silver solders, and brass (copper-zinc) brazing alloys are commonly known as hard solders or spelter solders.

Silver alloy is used extensively in modern warship construction for joining non-ferrous metals. You can use silver solder on pipes and tubes when the work is on location, without dismantling the system. Silver solder is much easier to use and control than brass when the brazing must be done in a tight spot, such as near the overhead or near a bulkhead. Silver solder is used extensively with piping. It may also be used on small sections of tool steel. Silver soldering alloy contains over 50 percent silver and has a melting point of 1450° to 1750° F. Silver brazing alloys contain 50 percent silver or less and have a low temperature melting point varying from 1070° to 1300° F. The use of silver alloys for joining metals is known either as SILVER SOLDERING or as SILVER BRAZING.

Brass rod or spelter (small grains of brass) may be used as filler metal for brazing copper and brass pipes, tubes, sheets, and fittings. Brass is also used to join unlike metals — brass to steel, brass to cast iron, or cast iron to steel. General repair work on machines and castings is usually done with brass rod. And brass is the best filler metal for brazing galvanized sheet and pipe. The common brazing or spelter solders are composed of approximately equal parts of copper and zinc. They melt at temperatures ranging from 1600° to 1700° F., depending upon

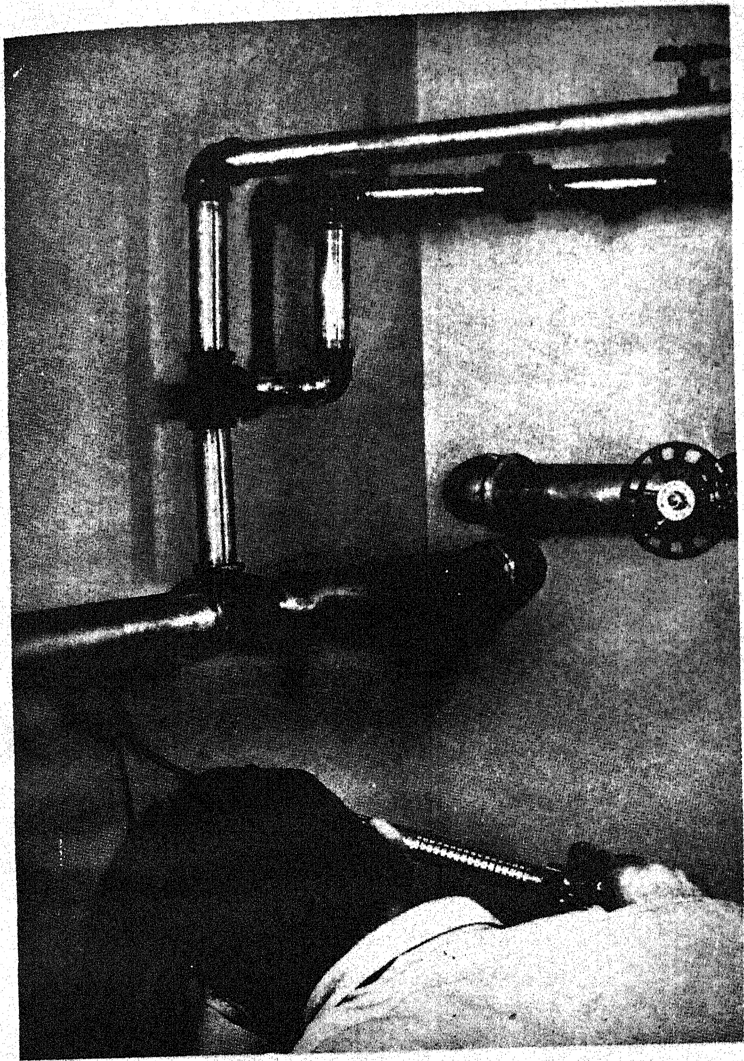


Figure 109.—Brazing near a bulkhead.

the proportion of copper and zinc contained in the alloy. The joining method done with brass rod or spelter is usually referred to as BRAZING.

Bronze rod is used to build up worn gear teeth, bearing surfaces, and shafts, and for joining metal parts which are not subjected to high temperatures. These copper alloy welding rods have a high-temperature melting point ranging from 1600° to 2250° F. This joining or building up process is known as BRAZE WELDING or BRONZE WELDING.

Figure 110.— Get it ready.

Clean and properly fitted joints are necessary for satisfactory bonding. All parts to be brazed must be thoroughly cleaned. Surface scale or oxides should be removed either by chemical or mechanical means. For the mechanical cleaning of rusty or corroded parts, you will find sanding, grinding, sandblasting, or filing effective (see figure 111).

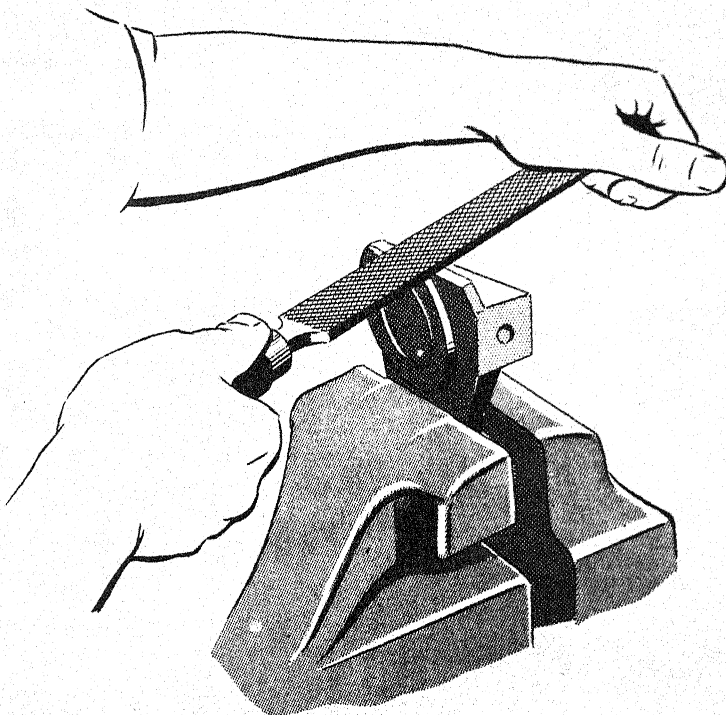


Figure 111.—Cleaning with a file.

A stiff wire brush is also a good tool to use (see figure 112). Oil, grease, or dirt of any description must also be removed as it interferes with good work. Heat may be used effectively for the removal of oil or grease. Don't attempt to braze dirty metal. You may get a weak, leaky joint that is full of pinholes.

Chemical cleaning is done with a cleaning agent which is usually designated by the term flux. Actually the flux has other functions besides that of a cleaning agent. It also protects surfaces after the work has been cleaned and during the heating process. And to the experienced Metalsmith it acts as an indicator of temperature during the heating.

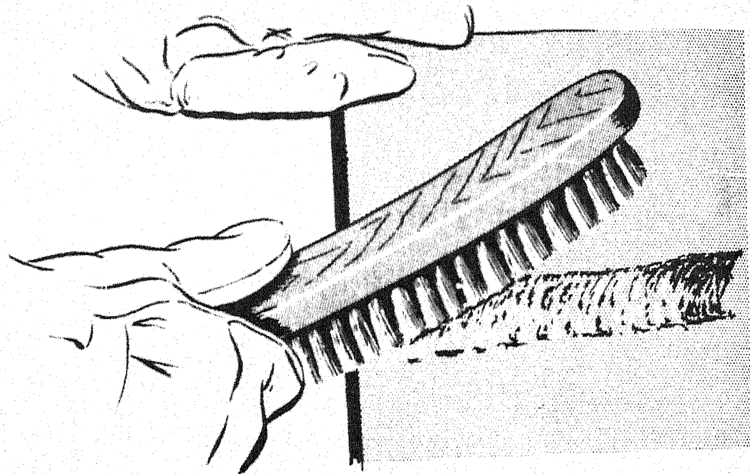


Figure 112. — Cleaning with a wire brush.

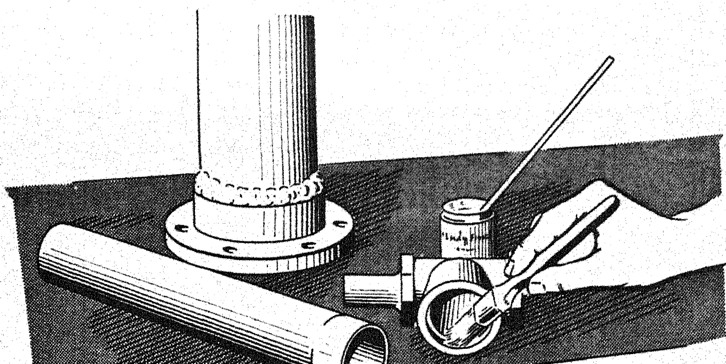


Figure 113. — Fluxing of parts.

Another important factor to be considered in the preparation of a joint for brazing is the clearance between the surfaces to be joined. This clearance will vary according to the alloy used,

type of joint, method of heating, and the metals to be joined. With free flowing alloys such as silver solders, closely-fitted joints within a few thousandths of an inch will give the best results (see figure 114).

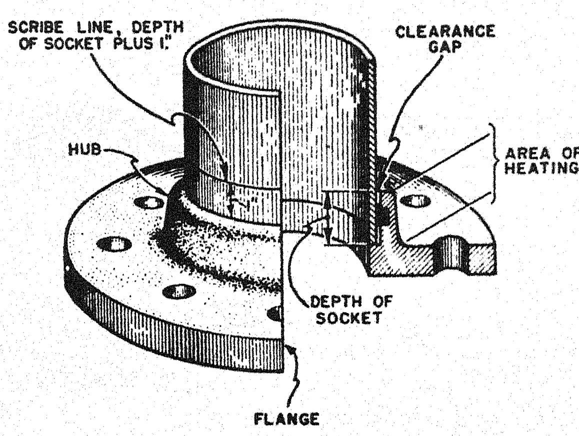


Figure 114.—Flange and tube showing clearance gap.

When welding rods are used it is common practice to make a V joint and fill the joint with successive layers of brazing alloy. When you get the joint cleaned and set up for proper clearance, apply flux.

FLUXES

The temperatures required for brazing cause a rapid oxidation of the surfaces of the job if it is exposed to air during the heating. A thin film of oxide will prevent proper bonding. The surfaces should therefore always be protected with some sort of a flux which is used to increase the flow of the brazing alloy and to increase its "stickability". The flux acts to prevent the oxidation of the metal surfaces and to remove the oxides already present. It brings the brazing filler into intimate contact with the metals being joined, and causes the filler to penetrate the pores of the metal thus forming a strong bond.

There are many prepared fluxes available; but, the Navy uses only those fluxes which meet certain specifications. Flux for silver brazing is covered by Navy Specification 51F4. The Navy also has a specification for a flux to use with copper base alloy. It is covered by Specification 51F8 (INT). INT means interim, indicating that this flux has been specified for the time being, awaiting proof of advisability of using it permanently. Regardless of the type of flux you select for the job, it is most important that you apply it in such a manner that all oxide film is removed. The flux should be a thin liquid at the brazing temperature in order to prevent inclusions of oxide which will later give trouble. The surfaces of both the joint and the brazing alloy should be protected with flux if the best results are to be obtained.

Flux may be used in three ways: dry, in paste form, or in hot, saturate solutions. When used in paste or hot solution, it is best to brush the flux over the surfaces. You should brush the flux on with a circular motion and have the flux extend outside of the joint or fitting as shown in figure 113. By brushing the flux on, you can get a more uniform coating and there is less chance for bare spots that will oxidize during the heating. When the brazing alloys are in granular form, the flux may be mixed with the alloy and the mixture spread along the joint. Strip, wire, or rod alloys can be coated by dipping the end into a can of flux paste before using. Ordinarily flux is applied when using rod alloys by heating the rod and dipping it into the flux. Or you may heat the rod and sprinkle dry flux on it. Sufficient flux to do the job will stick to the hot rod.

Borax or a mixture of borax and other chemicals is most often used as a flux for high-temperature brazing (1350° to 1800° F.) when brass filler is used. Up to a certain point heat causes borax to swell and bubble. Common crystalline borax, although it appears perfectly dry, contains approximately 47 percent water of crystallization. When the borax is heated this water is driven off, causing the borax to appear to boil. Borax may be mixed with water to form a paste, but because of the ability of borax to hold water, it will quickly take up the water and become crystalline borax again. Borax in the lump form should

be kept on hand and powdered as required. If commercial powdered borax is used, it should be kept in sealed glass jars.

Commercial fluxes are used in the same way as borax because they are usually made mostly of borax.

The flux used in brazing is called upon to do a number of things. It must protect the work after the surfaces have been cleaned. It must prevent the surfaces to be brazed from absorbing oxygen while the work is being heated to the right temperature to receive brazing alloy. It must clean the work, removing scale and oxides which have not been previously removed. It must act as an indicator of temperature so that the Metalsmith will know when the parts have reached the brazing temperature. And it must act as a protective cover at the edge of the joint so that the joint does not become oxidized.

There are many fluxes which have some of the desired characteristics and lack others. There are others which have all the desired characteristics and have additional characteristics which are objectionable. In selecting a flux, the following characteristics are considered essential:

1. The flux should be fluid and active at the melting point of the brazing alloy. Some fluxes are very active at the melting point of the alloy, but have a tendency to cake up or vaporize, and do not become fluid.
2. Good flux should remain stable and not change to a vapor rapidly within the temperature range of brazing.
3. The flux should dissolve all oxides and remove them from the brazing surfaces.
4. The flux should adhere to the brazed surfaces while they are being heated and not ball up and blow away.
5. The flux should be free from salts or metals which will cause a glare. Some fluxes contain sodium which will cause a bright yellow glare, and others contain lithium, which will cause a bright pink glare. A glare of this sort makes it difficult for one to see the alloy as it flows from the joint.
6. The flux should be easy to remove after brazing. Many fluxes will readily dissolve in warm water so that they may be washed off. Other fluxes will form a hard, glassy scale

on the work, which is difficult to remove. These should be avoided or rejected.

7. The flux should come in a form that can be easily applied to the clean surfaces, and will adhere to those surfaces. Paste is preferred. Many fluxes are available in powder form only and cannot be applied to the surfaces to be brazed in advance.
8. The flux should be free of odors. Some fluxes contain salts or acids which give off objectionable odors when heated.

Handy Flux, made by Handy & Harman Company, is one flux that meets Navy Specification 51F4. It is available in paste form and can be applied readily to the clean surfaces with a brush. The solvent in this flux is water. If the flux becomes thick or hard in use, it may be thinned by adding water. Handy Flux becomes liquid when heated and it has the appearance of water on the pieces to be brazed when a temperature of 1000°F. is reached. This watery appearance is the indication you must observe during the brazing operation to know approximately what temperature has been reached. Any excess flux on the joint may be removed by washing, either by dipping the parts in water or by wiping them with a wet rag.

In case a prepared flux is not available, a mixture of twelve parts of borax and one part boric acid may be used as a flux for solders with a high melting point.

For aluminum welding, good fluxes are prepared by a number of reputable manufacturers. Airco Napolitan or Matchless Fluxes, Oxweld Aluminum, Smith's Aluminum Flux, and Aluminum Company of America's No. 22 Welding Flux are representative of brands which have been used with satisfactory results.

For fusion welding of brass and bronze, the Oxweld Brazo or Airco Marvel fluxes are representative brands which have proven satisfactory. Others equally good are available on the market.

HEATING HINTS

The four principal methods of supplying the heat necessary for brazing are: heating by dipping the parts into a bath of the

molten alloy, called dip-brazing; heating by furnaces; heating by electrical resistance devices of various types; and heating by torches. You won't have much occasion to use the first three methods, but just in case you should hear them mentioned, the following definitions will serve to sharpen you up.

To dip-braze, the alloy is melted in a suitable container and covered with flux to prevent oxidation. The parts to be brazed are cleaned and assembled in a suitable jig to hold them in position, and are then dipped into the molten alloy. They may be removed almost immediately. The clean joints will be coated with the alloy, which will form the joint as soon as it has cooled. The jig must not be removed until the joint has cooled. The size of the container must be sufficient to accommodate the parts to be joined.

Another type of dip-brazing is done by means of the salt bath type of furnace. The parts to be brazed by this method are assembled and spelter solder is applied to the joint. Then the parts are immersed in a bath of molten salt, which melts the alloy and forms the bond.

Furnaces are used for certain types of brazing. The brazing alloy is applied either along the joint or by inserts, and the assembled parts are placed in the furnace. Figure 115 shows the use of a silver-solder insert. Furnaces with nonoxidizing atmospheres (remember the discussion in chapter 4) are preferred. But if the joint is properly protected with flux good work can be done in ordinary furnaces. The furnace should be large enough so heating can be done rapidly, and the temperature of the furnace should be considerably above the melting point of the brazing alloy.

The electrical resistance method is used on small parts. It is also used in those cases where a thin sheet of the brazing alloy can be inserted in the joint. The advantage of the electrical resistance method is that it puts the heat where it is needed and it works quickly.

Most of your brazing in the Navy will be done with heat supplied by an acetylene welding torch. A neutral or slightly reducing flame should be used in most cases, although for some

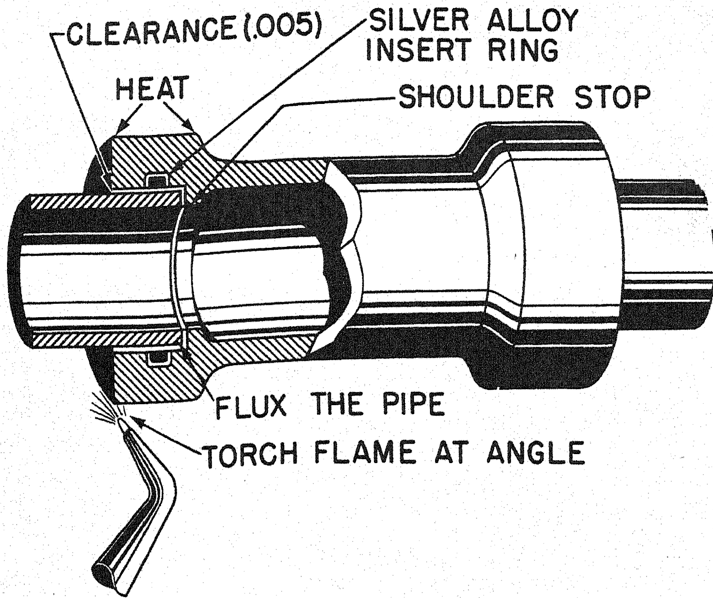


Figure 115.—Use of silver-solder insert.

types of bronze welding a slightly oxidizing flame is best (see figure 116).

Keep the inner cone of the flame from ¼ to ½ inch away from the metal. Play the flame over the surface with a circular, sweeping motion, so that you obtain uniform heating of the parts to be joined. The flame should be soft so that it won't blow or boil the molten filler metal.

Select a torch tip to suit the type of work you are doing. You'll ordinarily use sizes 4 or 6 for brazing sheet stock. The table in figure 117 may be used as a general guide for pipe work. When you silver solder you'll do well to select a soft lead-burning torch.

When using a torch, bring up the temperature of the parts until the flux on them is melted. Continue heating the parts to be joined until they are hot enough to melt the filler rod. The filler should be melted by the heat of the joint, not by the

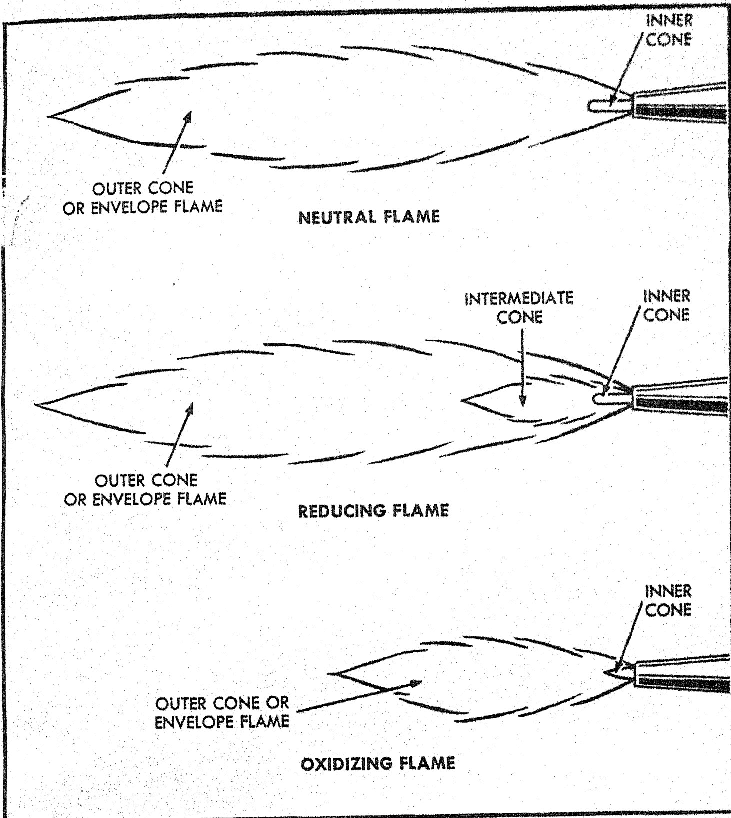


Figure 116.—Types of flames.

SUGGESTED TORCH TIP SIZES FOR BRAZING AND SILVER-SOLDERING PIPE

PIPE SIZE	TIP NO.	OXY. PRES.	ACETY. PRES.
1/4 and 3/8	4	8	6
1/2 to 2 1/2	6	12	10
3	8	12	10
4, 4 1/2, 5	8	15	12
6 and 8	9	20	15
10	10	20	15

Figure 117.—Tip sizes for brazing pipe.

948341 O—51——14

flame. It should flow like water wherever the flux has been applied. Avoid overheating. Use just enough heat to get the parts of the joint hot enough to melt and flow the filler metal.

You'll find that the toughest part of brazing and silver soldering is heat control. This depends in part upon your ability to manipulate the torch. Now that is something that you can't learn entirely from books. The best way to learn to control the heat is to get plenty of practice. It will also help to watch an expert braze up a few joints.

If you have heavy and thin metal sections to braze together, you'll have to be careful to avoid overheating the thin part. A good example is the brazing of thin copper tubing to a heavy cast fitting. If the same amount of heat were applied to the tubing as to the casting, the tubing would be overheated and probably burned. Therefore most of the heat must be directed toward the heavier part (see figure 118.)

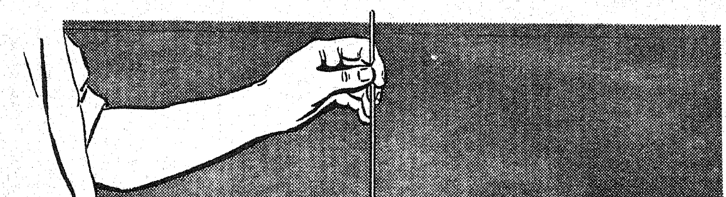


Figure 118.—Torch flame directed on heavier part.

Heavy parts and large areas must be preheated for best brazing results. Preheating may be done with a forge, furnace, oil-burning torch, gasoline torch, or with a welding torch. Use your Hauck burner (see figure 119) when you can—it's much more economical than acetylene.

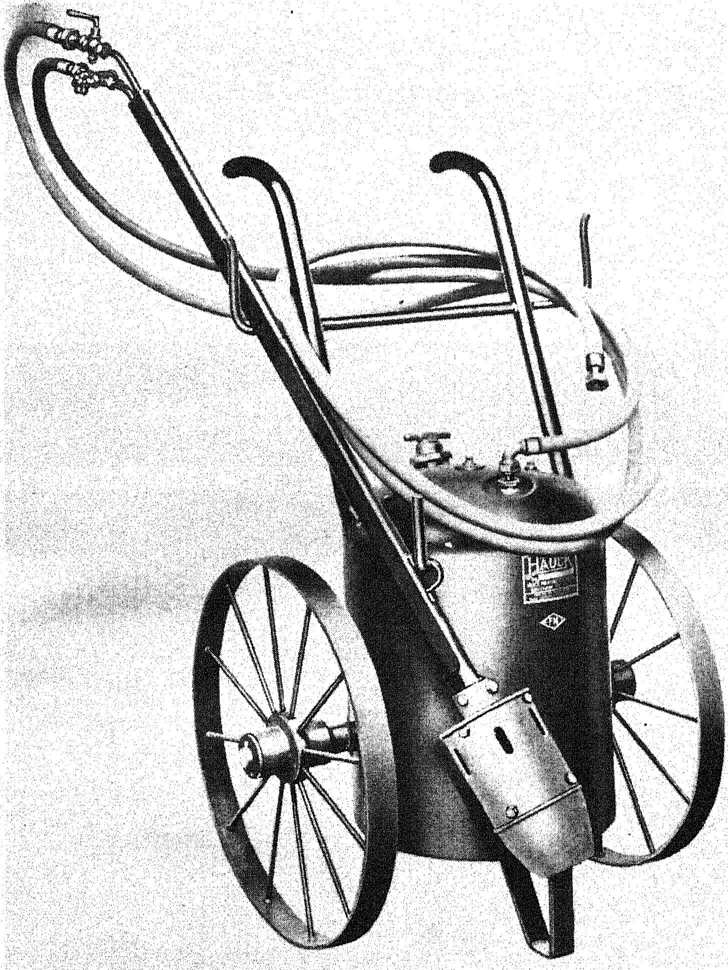


Figure 119.— Hauck burner.

You also need cooling control. Slow and uniform cooling is essential for a good joint. You can control and equalize the rate of cooling by postheating—heating after the joint is completely brazed. The lightest or thinnest metal should receive most of the postheating because it naturally cools faster than a heavy section. In other words, maintain a uniform heat throughout the whole joint as you allow it to cool slowly.

Avoid placing any stress on a brazed joint until it has cooled below 500° F. The filler metal is weak—has a low tensile strength — at higher temperatures. When metal is weaker at higher temperatures than when cooled it is said to be "hot short."

Brazed joints may be annealed and cold-worked without damage, but should never be hot-worked.

JOINING WITH SILVER ALLOYS

The piping systems aboard naval vessels include large quantities of non-ferrous (copper and copper alloy) and steel tubing or pipe. For that reason, it is important to understand the principles of silver soldering or silver brazing that is used for making joints in copper, brass, and copper-nickel piping systems.

Joining with silver alloys may be called SILVER SOLDERING or SILVER BRAZING. Both are done by the same method, the difference being the alloy used. Silver solders, you will remember, are alloys containing over 50 percent silver. Silver brazing alloy contains not more than 50 percent silver. Silver solders melt at 1450° to 1750° F., but silver brazing alloys melt at 1070° to 1300° F.

Joining with silver alloys is not a fusion process, as the base metals or the parts being joined are not heated to their melting temperature. The process of joining with silver alloys is really low-temperature brazing, since the melting points of the silver alloys are lower than those of brazing rods. The strength of the joint made with this process depends upon how well this thin film of silver alloy is bonded or sweated to the surface of the

base metals. Figure 120 is a microscopic view of a portion of a joint made with a silver alloy.

Silver alloys are used for joining parts made of various metals, the principal ones being copper, nickel, monel metal, stainless steel, brass, and bronze.

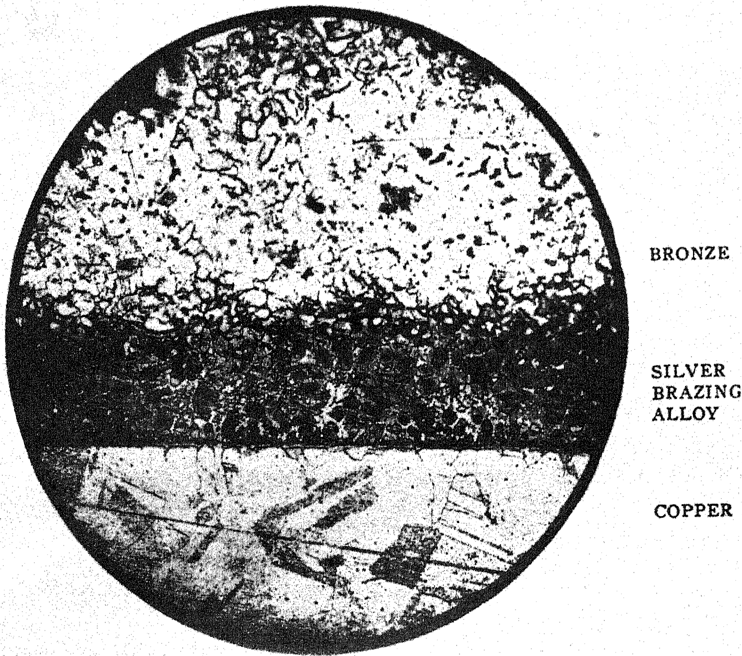


Figure 120.—Microscopic view of silver brazed joint.

Silver alloys are alloys of silver, copper, zinc, phosphorus, cadmium, and nickel. The percentage of these various metals determines the color of the alloy, its strength, and its melting point. Figure 121 indicates the method of identification of the various brazing alloys, and shows the Navy specification number, trade names, and proper use of each alloy.

The alloys used in silver brazing in naval work are covered by Specification 47S13. There are six grades of these alloys—Grades O, I, II, III, IV, and V (see figure 122).

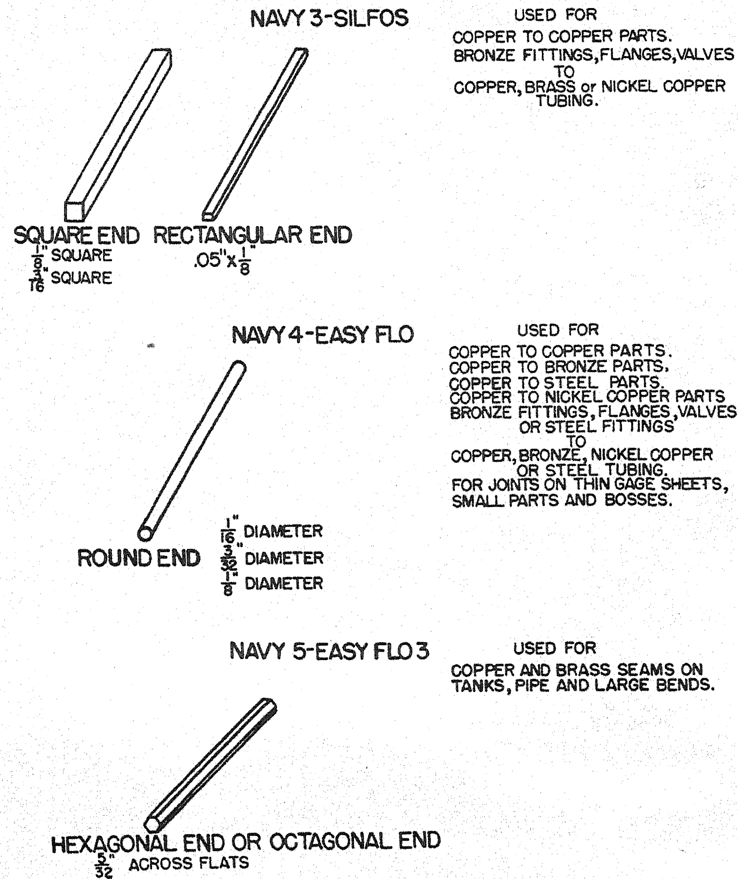


Figure 121.—Brazing alloys.

For making joints on ship's piping between bronze fittings, flanges, and valves, and copper and copper alloy tubing, Grade III is recommended and preferred.

For certain types of connections to very light parts made of brass or copper alloys, use Grade IV. Grade IV is also used for making joints between steel fittings and copper or copper

Trade Name	Navy Grade Number	Composition Percent	Melting and Flow Point	Distinguishing Shape	Suggested Usage
"AT" Special	O	Silver 20 Copper 45 Zinc 35	1430° F. 1500° F.	Thin Gage Sheet	Sealing Joints Operating up to 1230° F.
"DE"	I	Silver 45 Copper 30 Zinc 25	1250° F. 1370° F.	Thin Gage Sheet	Sealing Joints Operating up to 1050° F.
Easy Silver Solder	II	Silver 65 Copper 20 Zinc 15	1280° F. 1325° F.	Thin Gage Sheet	High Silver Content Primarily for Color Match.
Sil-Fos	III	Silver 15 Copper 80 Phosphorus 5	1200° F. 1300° F.	Rectangular or Square	For Joining Copper to Copper, Copper to Bronze, Nickel Copper to Bronze, Nickel Copper to Nickel Copper, and Other Copper Base Alloys.
Easy-Flo	IV	Silver 50 Copper 15 Zinc 17 Cadmium 18	1160° F. 1175° F.	Round	For Joining All Non-Ferrous Metals Plus Copper to Steel, Nickel Copper to Steel, Steel to Steel. *Note 1.*—Use only where proper tolerances can be maintained.
Easy-Flo 3	V	Silver 50 Copper 15 Zinc 17 Cadmium 16	1195° F. 1270° F.	Hexagonal or Octagonal	For Joining All Non-Ferrous Metals Plus Copper to Steel, Nickel Copper to Steel, Steel to Steel. *Note 2.*—Use where close tolerances can not be maintained.

Figure 122.—Silver brazing alloys.

alloy tubes. For making joints between steel fittings and steel or ferrous alloy tubes, Grade IV alloy must also be used.

For making brazed seams in sheets, tubes, and other light-gage metals, Grade V is recommended and is preferred, although Grade IV may be used.

The silver brazing alloys described above are covered in Navy Specification 47S13, and have the following characteristics which are desirable in silver brazing work:

1. They have a low melting point.
2. They have high tensile strength.
3. They are highly resistant to corrosion.
4. They flow readily at the lower brazing temperature range.
5. They will bond readily to copper and copper alloy parts.
6. They may be distinguished by color in the molten state so that the Metalsmith may tell them when the joints are completed.
7. They will, when properly applied, give joints that are free from porosity caused by gas inclusions or vaporizing of the alloys.

YOU NEED TO KNOW

When you are to join parts with silver alloy, you need to know a few natural laws that govern the flow of heat through metal parts. The flow of heat through metal is called HEAT CONDUCTIVITY (see figure 123).

1. Heat always flows from a hotter to a cooler body. Thus, when two pieces are to be joined with a silver alloy, both pieces must be brought to a temperature sufficiently hot to melt the alloy before the alloy will flow onto both. You can heat both pieces independently with a torch if they are separated. If they are touching, you may heat one piece and the heat will be conducted to the cooler piece (see figure 124).

2. Alloy in the molten state will always flow from the cooler to the hotter spot on a heated surface (see figure 125). The alloy flows in the opposite direction to the flow of heat. Thus,

when two parts are to be joined, if one part has been tinned, the other part must be heated to a higher temperature so that the alloy will flow and bond to it.

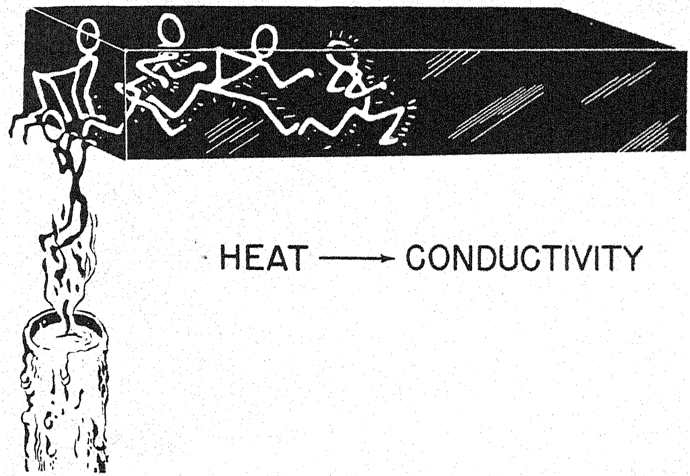


Figure 123.—Heat conductivity.

3. Alloy and flux cannot occupy the same space. When you set up a joint, leave a clearance so that the alloy can flow in and fill up the joint, and don't forget to leave an opening for the flux to get out. Heat should be applied as indicated in figure 126, so that the flux will flow out when the alloy reaches the bonding temperature.

4. Heat travels faster through some metals than through others. A metal through which heat travels fast is said to have high conductivity. Copper is such a metal (see figure 127). This explains why in brazing work some metals remain cool while others tend to overheat. Also you can see that in joining parts of different kinds of metals more heat must be applied to the one having high heat-conductivity, because more heat will be taken away from the brazed area by the part having high conductivity. Thus steel parts will reach the joining temperature more quickly than copper parts, and the steel part can be more easily overheated because the heat is being carried

away slower. Thus, in joining steel parts, you use a smaller torch tip and direct less heat on those parts than when joining copper parts of the same size.

5. When joining with silver alloys, the parts to be joined must be at the joining temperature (hot enough to melt the alloy) at the time the alloy is added. If one piece of the joint

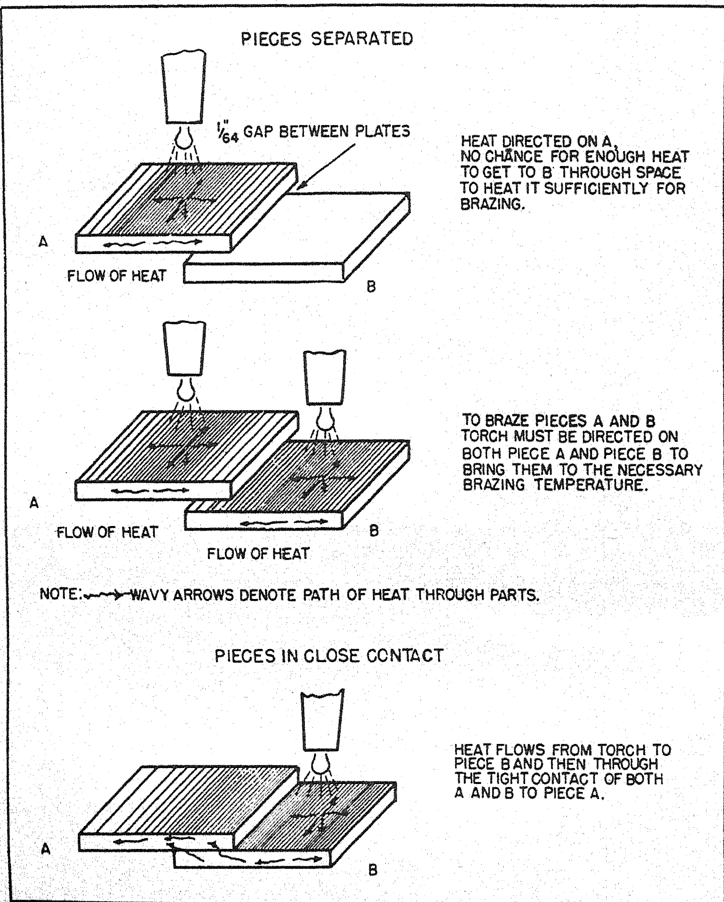


Figure 124.—Flow of heat.

is hot enough and the other is not, the molten alloy will flow on one piece and be quenched by the other, and it will not bond to the cooler piece.

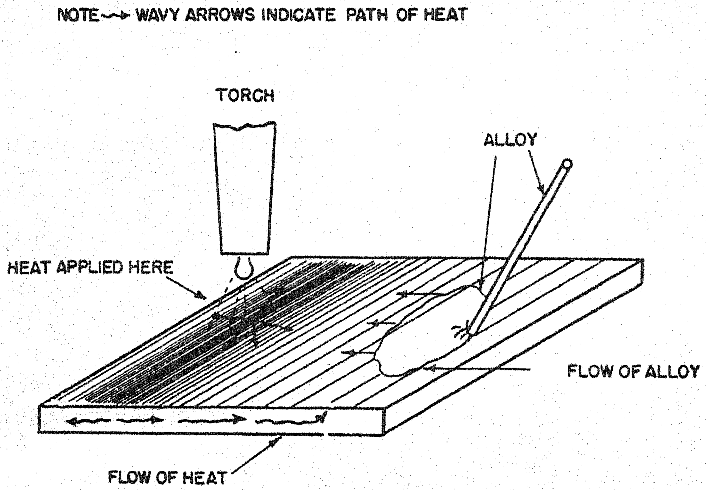


Figure 125.—Molten alloy flows from the cooler to the hotter spot on a heated surface.

When using a silver alloy, a joint can best be made by making the joint in portions, usually 2 to 3 inches at a time, and by using equipment which will enable you to heat only the portion that is being joined.

For both shop and ship work you will find light-weight torches and light-weight hose easier to handle. You can guide the flame more easily to that portion of the joint being bonded. Heavier equipment tires you out and prevents you from following the best procedure for making the joints. To make the joint in portions, you need equipment that will allow you to heat only that section of the joint to be bonded and no other.

An oxyacetylene torch should be used for making the joint. Torches should be fitted with various sizes of tips for making joints in materials of different thicknesses. One size tip can't be used for making joints on all thicknesses of materials. The

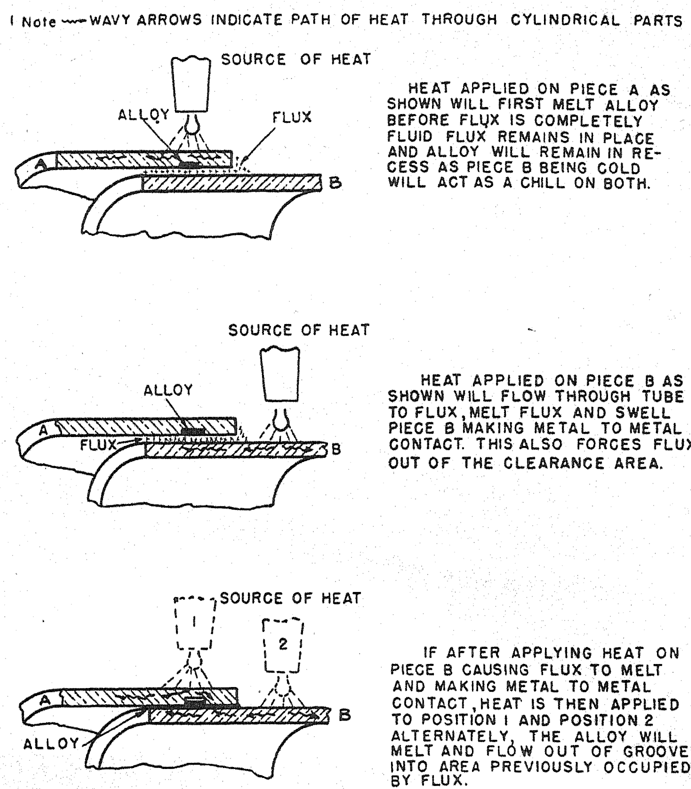


Figure 126.—Alloy and flux cannot occupy the same space.

tips should be designed to heat a large area and still allow little or no "bounce" (reflected heat). Figure 128 shows how tips are made to get different shaped flames at the end of the tip.

As the velocity of the gas increases due to the smaller inside diameter of the tip, the length of the flame cone gets longer and the size of the bulb becomes smaller. Type *A* has the lowest velocity and heats the biggest spot. This is the type that should be used in joining with silver alloys. You can use a tip of

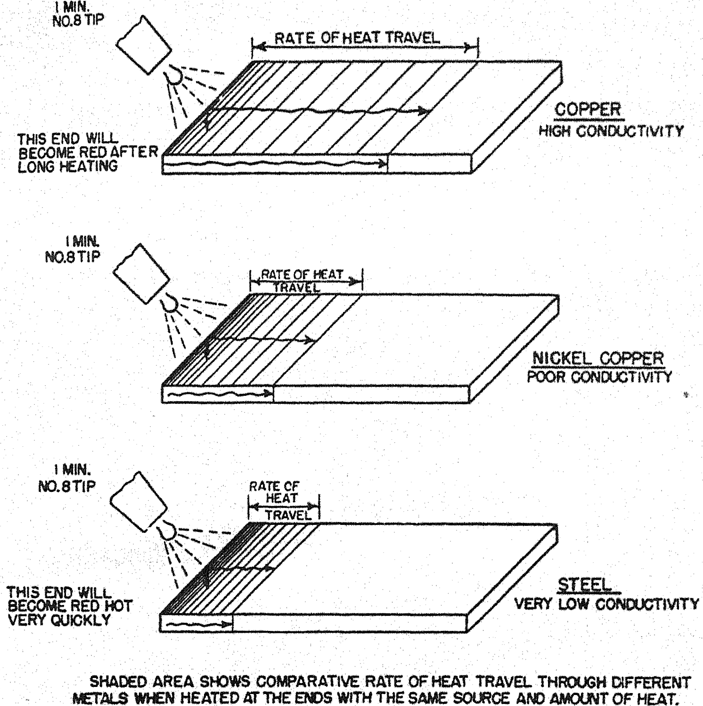


Figure 127.—Heat travels faster through some metals.

Type *A* to make joints adjacent to wood or painted surfaces without reflecting enough heat to do any damage.

When you choose a torch for silver soldering or silver brazing, it should be one fitted with a soft copper tube at least 10 inches long between the tip and the torch handle (see figure 129).

You can bend this tube extension wherever it is needed to heat the portion to be joined. You should always use a torch with this flexible extension for work aboard ship, as without it you are unable to heat properly the parts to be joined in many locations in the piping system.

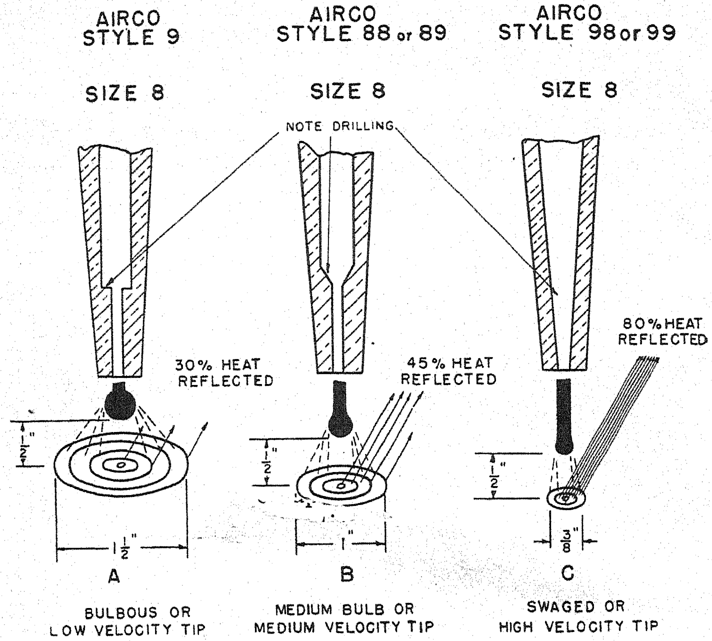


Figure 128.—Comparison of heat bounced off work by different types of tips.

MAKING THE JO...

... —Alloy and flux co...

There ar... ...aking joints with silver alloy: the INSERT ... FEED-IN METHOD.

When using the INSERT METHOD, a flange or fitting is used in which the manufacturer has pre-inserted a strip of the silver alloy. The parts to be joined are cleaned with emery cloth, sandpaper, or some other suitable abrasive. A suitable flux is then applied with a brush. Brush the flux on with a circular motion and have the flux extend outside of the fitting (see figure 130). Fit the two parts together and aline them. A vise is a handy tool to use when joining pipe and fittings. Light off the torch, and gripping it in both hands as shown in figure 130, direct the heat on the tube or thinner portion to swell it up.

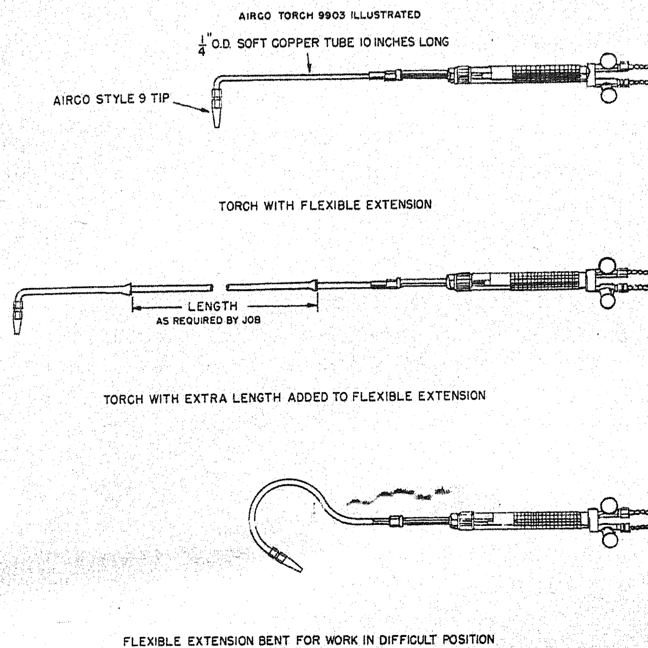


Figure 129.—Lightweight oxyacetylene torches, showing extensions.

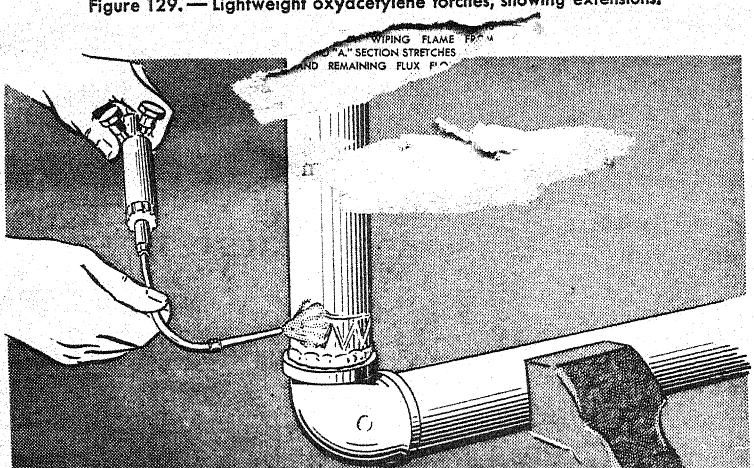


Figure 130.—Holding parts in position.

The lines drawn on the tube in figure 130 indicate the path of th. torch during heating.

In the case of joining a fitting and a piece of tubing, the flux-coated tube is inserted into the fluxed fitting and the clearance area is thus filled with flux. The heat is then applied to the tubing to swell it up and bring the surface of the metal into contact with the inside surface of the fitting. The clearance area is thus closed, forcing the flux from either end of the joint. In this procedure both parts must be heated to the joining temperature (see figure 131), at which time the alloy will automatically flow out or be squeezed out into the joining area. In the insert method the alloy will not leave the insert unless both parts are at the proper bonding temperature. If one of the parts is up to temperature and the other is not, the alloy will not flow from the insert because it will be cooled or quenched by the surface not yet up to temperature. By playing the torch over a 2- or 3-inch section of the fitting you can cause the fitting to stretch or open up and let whatever remaining flux there is present run out. Then hold the torch off the work and the fitting will return to normal size and force the alloy to the edge of the fitting. You may be sure that a good joint is formed

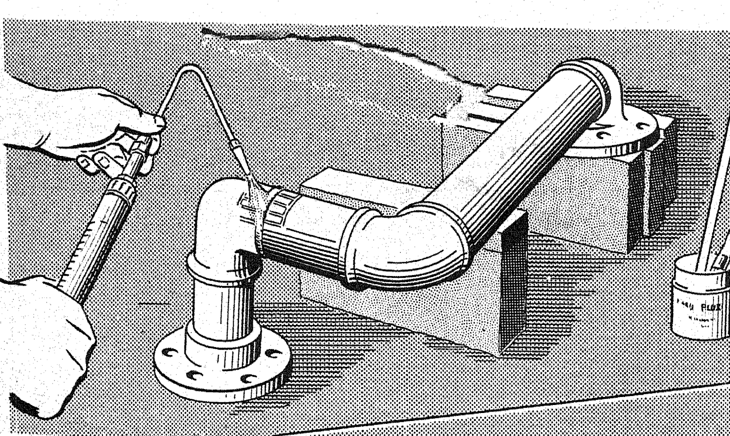


Figure 131.—After the tube is heated, heat the fitting.

when you can see the alloy at one or both of the edges of the joined area. Figure 132 shows the process of joining by the insert method step by step.

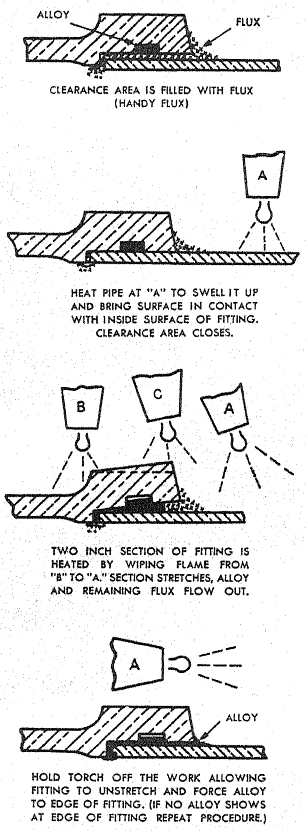


Figure 132.—Silver alloy insert method of joining.

The FEED-IN METHOD, sometimes called the STICK-FED METHOD, is accomplished by feeding the alloy by hand into the area to be joined. In this method you must remember that the alloy always flows along a heated surface from the cooler to the hotter section (see figure 133). In other words, the alloy

flows toward the source of heat or to the point where the heat is being applied. In this method, the metalsmith must always feed alloy at the outer edge of the joint while directing heat at the inner edge of the joint (see figure 133).

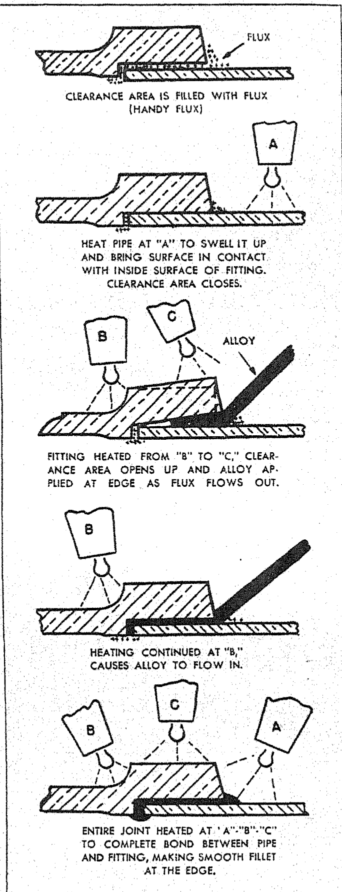


Figure 133.—Feed-in method of joining with silver alloy.

The parts to be joined are cleaned and fluxed in the same manner as in the insert method. When the parts are fitted together the clearance area is filled with flux. After alining

the parts, in the case of a tube and fitting or a pipe and fitting, heat the tube or pipe enough to make them swell (see figure 134).

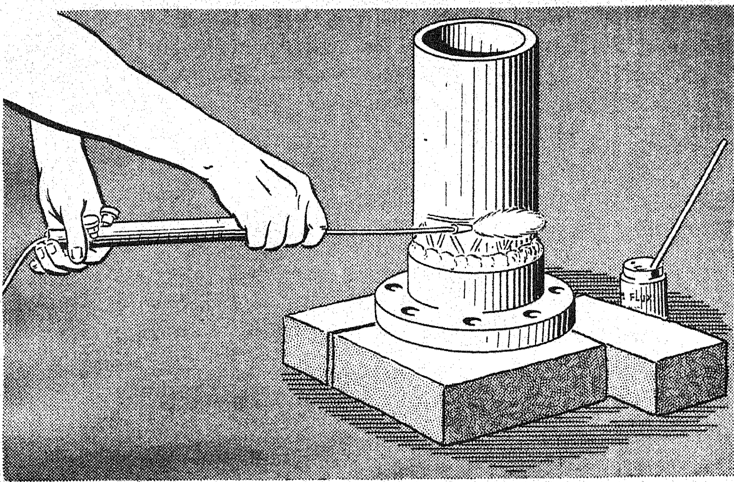


Figure 134.—Heating tube to swell it up. Chalk lines indicate path of torch.

This tightens the tube or pipe in the fitting sufficiently to aline the joint. Heat is then applied to the fitting or the inner edge of the joint at the same time that the alloy is fed at the outer edge of the joint. As the alloy will flow toward the hottest section, it will flow through the joint toward the point at which the heat is being applied. In this method, it is left entirely to the judgment of the Metalsmith to determine when both parts are properly heated and when to feed the alloy. It is also left to his judgment to determine if sufficient alloy has been fed into the joint to completely fill the space between the two parts being joined. The Metalsmith must also be skillful in manipulating the torch flame to be certain that the heat is applied to the proper point to cause the alloy to flow from the cooler to the hotter section. In the feed-in method, alloy visible at the edge of the joint does not necessarily indicate that the entire joint is filled with alloy.

The difference, then, between making a joint by the insert method and with the feed-in method is in procedure. When

using the insert method, you heat a section and remove the torch, and the alloy is automatically squeezed out from the insert, whereas in the feed-in method, after you heat a section the heat must be directed to the inside edge of the joint while the alloy is being fed in at the outside edge of the fitting (see figure 135).

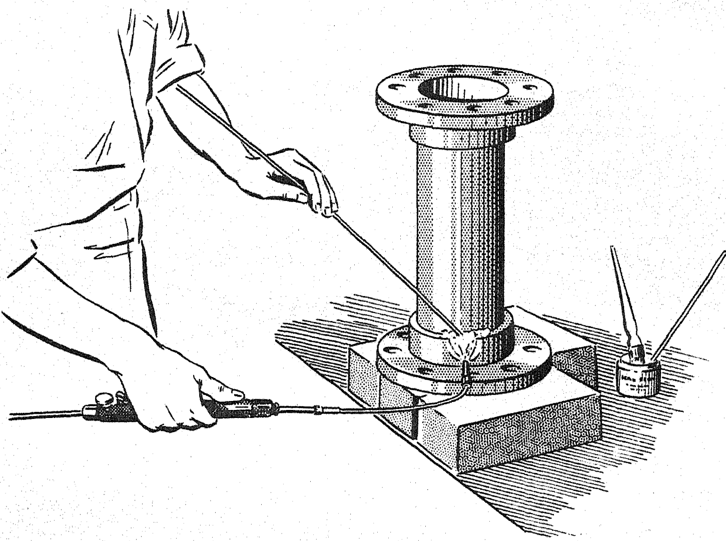


Figure 135.— Feed-in method. Notice torch flame directed on flange hub while alloy is added into clearance gap.

WHAT IS BRAZE WELDING

Braze welding is a process used for joining or building up the high-melting-point metals by use of brass and bronze alloys which melt at much lower temperatures. Cast iron, malleable iron, and steel are high-melting-point metals. In braze welding, the base metal is heated to around 1400° F. or approximately cherry red, but never to the melting point. The bronze or brass filler metal is then melted, and flows over the base metal.

Braze welding is based on the theory that certain copper alloys will join so closely with the molecules of the base metal that a very strong union or bond is formed. This action de-

pends, however, on three factors: having a suitable base metal, heating it to sufficient temperature, and cleaning its surface thoroughly by chemicals in the form of flux. The molten copper alloy covers the base metal in a thin film in the same manner that water spreads over a clean glass plate. The bond formed depends upon the molecular forces at the point where the copper alloy and the base metal meet. The copper alloy generally forms a thin layer, practically the same as plating the base metal. This action is called tinning.

In addition, the constituents of the alloy—copper, zinc, tin, and others—diffuse into the base metal. The constituents of the base metal also diffuse into the copper alloy. This all takes place within a narrow zone where the welding alloy meets the base alloy. This process is known as interalloying and is apparent only when examined under a microscope. Finally, the action of the molten copper alloy on the base metal surface opens up the crystalline grain structure of the base metal and allows the alloy to penetrate the base metal along the grains. These factors, combined, account for the very great strength of the bond between the copper-alloy and the base metal.

WHY USE BRAZE WELDING?

The fact that braze welds are made without melting the base metal greatly simplifies the welding procedure. It is easier to make good joints by this method. Since braze welding requires less heat than fusion welding, the speed of welding is increased. Less time and less gas are required to do a given job than are necessary for fusion welding.

Because of the lower temperatures required for braze welding, preheating is also easier. All you really need to do is to preheat the part to black heat before braze welding. Naturally, the effects of expansion and contraction are much less than in fusion welding. As a result, most of the braze welding operations can be done with only local preheating—that is, preheating the portion of the machine or casting that is to be braze welded. In many cases, this makes it possible to repair broken castings and other parts in place, thus saving time and expense of disassembling and reassembling.

As they cool bronzes yield, or give, until the temperature is below 500°F. Even at normal temperature they yield slowly under low stresses. This yielding doesn't weaken the bronze metal, but it does serve to relieve the stresses in a casting which has been braze welded. At least, more of the locked-up stresses are relieved than would be if the castings were welded with cast iron. The ductility of the braze welded metal acts further to take up any slight readjustments in stresses that develop after the welded parts have been put into service.

HOW BRAZE WELDING IS USED

Braze welding is widely used in the repair of gray iron castings. Not only is it used for repairing broken castings, but also in the rebuilding of missing or worn parts, such as gear teeth or valve discs and seats. Pistons, rotary valves, guides, and other sliding surfaces on pumps, engines, and machinery parts may be successfully repaired and rebuilt with braze welding. This latter operation is called "bronze-surfacing".

Braze welding is also the only practical method of repairing malleable iron. Malleability, you will remember, is developed by a special heat-treatment which is destroyed by the high temperature required for fusion welding. The comparatively low temperatures required for braze welding, however, do not affect the casting noticeably.

HOW BRAZE WELDING IS NOT USED

1. Braze welding should not be used for the repair or rebuilding of castings where the difference in color between the bronze and cast iron would be objectionable. Nickel bronze welding rods are sometimes used when color match is important.
2. Braze welding should never be applied to parts which will be subjected to high temperatures—higher than 650° F.
3. Braze welding should not be used in most cases to repair working parts or containers used in chemical processes. Strongly alkaline solutions, for example, will affect bronze but not cast iron. In this case, obviously, joining by fusion

welding should be done with cast iron rather than joining by use of braze welding.

BRAZE WELDING ALLOYS

The best bronze welding rod is one which has a copper-zinc ratio of 60 percent copper and 40 percent zinc. This ratio produces the best combination of high tensile strength and ductility. Because of its relatively low melting temperature, this alloy is used as a basis for the so-called bronze welding rods. Actually the term bronze is not correct, since this alloy, known as Muntz metal, is really a brass. The alloy possesses considerable strength when hot and has the narrowest freezing range (solidifies quicker) of the entire usable copper-zinc combinations. This is an additional advantage, as a quick-freezing alloy has much better weldability than one which remains mushy over a wide temperature range.

Most of the commercial bronze welding rods are modifications of this 60/40 copper-zinc alloy, with low alloy additions of tin, iron, nickel, manganese, silicon, and other ingredients. These ingredients are included to —

1. Increase tensile strength.
2. Improve flowing qualities.
3. Make the rod tin readily when used with a suitable flux.
4. Deoxidize the weld metal.
5. Obtain a deposit which is free from slag inclusions or blowholes.
6. Reduce the tendency to fume due to overheating.
7. Increase the hardness of the deposited metal for greater wear resistance.

PREPARING FOR THE JOB

If you are joining edges ¼ inch or less in thickness, chip the surface until you have a bright metal edge. If the parts are over ¼ inch thick, you will need to bevel the edges to give about a 90° V. The best way to bevel edges is with an air

hammer, or with a hand chisel and sandblast. Don't machine or grind cast iron or malleable iron for braze welding, as the grinding tends to smear the graphite particles over the surface in such a way as to interfere with the tinning. Neither is it a good practice to bevel the welding V with a torch, unless the oxides and free graphite are removed from the surface before braze welding. If the kind of job that you are doing makes machining, grinding, or torch-beveling necessary, then finish the surfaces by chipping or sandblasting. You can also remove the graphite smear by searing with your torch flame. To sear, use an oxidizing flame and heat the parts to a dull red. The metal for at least ½ inch back from the top edge of the V should be thoroughly cleaned to permit easy tinning.

Coarse-grained soft castings are harder to tin than close-grained castings. A cast iron part which has been in contact with fire, such as a heating boiler section, will sometimes be difficult to tin. The same is true of castings that have been long exposed to steam and oil at high temperatures. Also, castings which have been in salt water or chemicals for some time may be difficult to tin. One method of making such pieces easier to tin is to alternately heat and cool the casting. In the more difficult cases it may be necessary to machine off the affected surfaces of the metal to make it take the bronze.

Once you have the parts properly cleaned and tinned, the next step is to aline the parts. Obviously, the parts must be placed in proper alinement and kept in their relative positions during the brazing process. You can best accomplish this by using clamps and by tack welding.

PREHEATING PARTS

In braze welding, a casting must be heated along the line of the weld. This sets up certain strains and stresses, due to expansion and contraction, unless the casting is properly preheated. In a small casting, up to about a hundred pounds, the heat from the torch is sufficient to preheat the entire casting. Larger castings should, however, be more thoroughly preheated. Besides providing for the relief of strains and stresses, pre-

heating speeds up the braze welding operation and requires the use of less oxygen and acetylene.

You can weld large castings without preheating by allowing for expansion and contraction, but it is generally safer and more satisfactory to preheat. Preheating can be done with your torch or with an improvised firebrick furnace covered with asbestos paper. Or you can use an oil or gas burner. At times, castings attached to a machine may preferably be welded in place. Often such castings can be preheated by playing the flame along the line of the weld and protecting the surrounding surfaces with asbestos paper.

USING FLUX IN BRAZE WELDING

The use of a high quality flux is essential in braze welding. It is needed for two reasons: (1) to clean the oxide that is formed ahead of the welding zone, due to the oxygen in the air, and (2) to dissolve the oxides formed in the brazing operation. Use plenty of flux in the tinning operation, but in filling the V you should use flux sparingly. This avoids too much reduction of the oxide film covering the molten pool. When you see that flux is required, it should be added carefully. The puddle should not be made mirror clear but left slightly clouded with oxide. Where the braze welding is rapid, it is best to coat the rods entirely with flux. If the operation is slower, as with heavy castings, you can dip the hot end of the welding rod into the flux and add to the puddle as required.

ADJUSTING THE FLAME

For braze welding a slightly oxidizing flame is used. To obtain the desired flame, you adjust the flame to neutral, and then open the torch oxygen needle valve slowly until the inner flame cone has been slightly reduced in length. Periodical checks should be made to be sure that this adjustment is maintained. A slightly oxidizing flame helps to secure a better bond between the bronze and the base metal. It also assists in keeping a slight film of oxide over the puddle. This film of oxide serves to protect the weld metal from the oxygen in the air.

TINNING THE PARTS

After the parts have been properly prepared — cleaned, fluxed, alined, and preheated if necessary — the parts are then tack-welded together. The metal is then heated with a torch at the point where the braze weld is to start. Play the torch flame over the part to be heated, using a circular motion. As the base metal gets hot, test its temperature with a drop of molten bronze from the welding rod. When the heated metal is just at the right heat (approximately cherry red) the molten metal from a sufficiently fluxed bronze rod will spread evenly over the surface when it hits. This produces a tinning coat on the base metal.

You can tin the base metal in braze welding only when the conditions are just right for it. If the base metal is too cold, the bronze is sticky and will not run out and spread over the heated surface as it should. If the base metal is too hot, the bronze will form little balls like drops of water on a hot stove. If the temperature of the base metal is right and the tinning is done properly, the molten bronze will spread over the surface like water spreading over a clean, moist surface. Tinning is the most important step in the braze welding process. Tinning forms the bond or molecular union between the braze weld metal and the base metal.

BRAZE WELDING PROCEDURE

As the tinning action is in progress, you continue to feed the braze weld metal into the molten metal to build the weld up to the desired size. The puddle should be small in size, but increased as it is moved forward, until it completely fills the V and a full sized braze weld is made. You must exercise care to be sure that the tinning action takes place continuously, just ahead of the puddle. Good braze welding combines into one continuous operation the tinning action and the building up of the braze weld to the desired size.

The inner flame cone is kept from 1/8 to 1/4 of an inch away from the surface of the metal. Usually the flame is pointed ahead of the completed part of the weld at an angle of about

45°, with the puddle under and slightly behind the flame. You vary the angle, however, when welding in flat, overhead, and vertical positions. Also the angle will vary with the size of the puddle being carried, the nature of the surface, and the speed of welding.

Bright spots on the metal in the puddle mean that oxides and impurities are present and should be worked out with the torch flame or with flux. Don't use too much flux, though, as this is wasteful and prevents your making the best joint. Use just enough flux to get a good tinning action between the braze weld metal and the base metal. The proper rate of braze welding is controlled by the rate of tinning; never flow the rod faster than the tinning action progresses.

It may be necessary to deposit the bronze in layers when braze welding heavy materials. If such is the case it is most important that the tinning of the base metal be a good job. If the tinning is good and fusion between the first and successive layers is thorough, a strong braze weld is assured.

COOLING THE JOB

After you have finished the braze welding operation, you should play the torch over the weld and on either side of the weld for several inches. The size of the weld and the size of the casting determine the size of the area that should be heated. Continue to heat until all sections of the part have been brought to even heat. If the repaired part is small, bury it in dry slaked lime. If it is large, cover it with asbestos cloth. In either case allow it to cool slowly. The parts repaired should be protected from drafts and cold air which would cause it to cool unevenly. Never place a braze-welded joint under stress until it has completely cooled.

USE YOUR KNOWLEDGE

You will find that much of your work as a Metalsmith will be concerned with the repair of parts. Whether you are repairing an old part or fabricating a new one, you'll find that almost every job you do will include some form of joining. You will

have to use your knowledge to choose the best method for joining a particular part. The method will depend upon the use to which the part is to be put, the material of which it is made, and in some cases, the accessibility of the part and the availability of the tools and materials for joining. Remember that there is always a best way of doing a job and do it that way if circumstances permit. If, however, you get caught in a tight spot, and you can't get your hands on the preferred tools and materials, USE YOUR KNOWLEDGE — GET THE JOB DONE.

QUIZ

Select the one best answer to each of the following statements.

1. The term brazing is sometimes referred to as —
   (*a*) Soft soldering.
   (*b*) Welding.
   (*c*) Hard soldering.
   (*d*) Fusion of base metals.

2. Any joining operation of metals performed at temperatures lower than 1000° F. is termed —
   (*a*) Welding.
   (*b*) Brazing.
   (*c*) Soldering.
   (*d*) Silver soldering.

3. The melting point of silver solder alloy (over 50% silver) ranges from —
   (*a*) 250 to 450°F.
   (*b*) 1070 to 1300°F.
   (*c*) 1450 to 1750°F.
   (*d*) 1600 to 1700°F.

4. The melting point range of silver brazing alloys of less than 50 percent silver is —
   (*a*) 700 to 1000°F.
   (*b*) 1070 to 1300°F.
   (*c*) 1450 to 1750°F.
   (*d*) 1600 to 1700°F.

5. A brass brazing rod melts at a temperature ranging from —
   (*a*) 1070 to 1300°F.
   (*b*) 1450 to 1750°F.
   (*c*) 1600 to 1700°F.
   (*d*) 1600 to 2250°F.

6. The melting point range of bronze welding rod is —
   (*a*) 1070 to 1300°F.
   (*b*) 1450 to 1750°F.
   (*c*) 1600 to 1700°F.
   (*d*) 1600 to 2250°F.

7. To prevent rapid oxidation caused by the temperatures required for brazing, one should use a uniform coating of —
   (*a*) Flux.
   (*b*) Grease.
   (*c*) Lead.
   (*d*) Tin.

8. To insure a uniform coating, paste or saturated solution fluxes should be applied with a —
   (*a*) Cloth.
   (*b*) Finger.
   (*c*) Brush.
   (*d*) Spray.

9. The flux most commonly used for high temperature brazing when a brass filler is used is —
   (*a*) Rosin.
   (*b*) Stearine.
   (*c*) Zinc chloride.
   (*d*) Borax.

10. A brazing flux which contains salts or metals will —
   (*a*) Strengthen the joint.
   (*b*) Cause a glare.
   (*c*) Spoil the joint's appearance.
   (*d*) Form pinholes.

11. At the melting point of the brazing alloy, the flux should —
   (*a*) Cake up and vaporize.
   (*b*) Ball up and blow away.
   (*c*) Give off an identifying odor.
   (*d*) Be fluid and active.

12. When a prepared flux is not available to use with high-melting-point solders, it is possible to use —
   (*a*) Tallow.
   (*b*) A mixture of borax and boric acid.
   (*c*) Muriatic acid mixed with water.
   (*d*) Copper sulphate.

13. The most frequently employed source of heat for hard soldering is the —

(*a*) Forge.
(*b*) Electrical resistance.
(*c*) Furnace.
(*d*) Acetylene torch.

14. The type of torch flame which is made up of three cones is referred to as—

(*a*) Reducing
(*b*) Neutral
(*c*) Brazing
(*d*) Oxidizing

15. The size of torch tip to be used for brazing and silver soldering ¼″ and ⅜″ pipe is —

(*a*) #4.
(*b*) #6.
(*c*) #8.
(*d*) #10.

16. The rate of cooling for a brazed joint can be controlled and equalized by —

(*a*) Quenching.
(*b*) Placing in an oil bath.
(*c*) Postheating.
(*d*) Annealing.

17. A brazed joint should not have any stress placed upon it until it has cooled below —

(*a*) 250°F.
(*b*) 500°F.
(*c*) 750°F.
(*d*) 1000°F.

18. To seal a joint in a ship's piping which operates up to 1230°F, one would use silver brazing alloy, Grade —

(*a*) O.
(*b*) I.
(*c*) II.
(*d*) III.

19. The silver brazing alloy recommended for use only where proper tolerances can be maintained is Grade —

(*a*) O.
(*b*) I.
(*c*) II.
(*d*) V.

20. The flow of heat through metal is called —

(*a*) Heat conductivity.
(*b*) Heat treating.
(*c*) Ductility.
(*d*) Drawing.

21. On a heated surface, molten alloy will always —

(*a*) Flow from the hotter to the cooler spot.
(*b*) Flow the same direction as the heat flows.
(*c*) Require torch pressure for flow.
(*d*) Flow from the cooler to the hotter spot.

22. When brazing a joint adjacent to wood or painted surfaces, the torch tip size best suited is —

(*a*) Type A, Style 9.
(*b*) Type B, Style 88.
(*c*) Type C, Style 98.
(*d*) Not important.

23. The two methods used for making joints with silver alloy are —

(*a*) Insert and feed-in.
(*b*) Feed-in and sweating.
(*c*) Tinning and insert.
(*d*) Alloy-bath and feed-in.

24. If two parts being joined are not of the proper bonding temperature, the insert alloy will not flow because the cooler surface —

(*a*) Does not allow sufficient tolerance for flow.
(*b*) Expands and freezes the two together.
(*c*) Quenches the alloy.
(*d*) Case-hardens the insert.

25. When using the feed-in method in brazing a joint, the alloy should be —

(*a*) Fed in through a small hole in one part of the joint.
(*b*) Fed in at the outer edge of the joint.
(*c*) Placed in the joint prior to fluxing.
(*d*) Fed in at the same place that the heat is applied.

26. When the base metal is heated to approximately 1400°F and bronze or brass filler metal is melted and flowed over the base metal, it is referred to as —

(*a*) Metal build-up by bath.
(*b*) Fusion welding.
(*c*) Flow brazing.
(*d*) Braze welding.

27. Braze welds should never be applied to parts which will be subjected to temperatures higher than —
(a) 650°F.
(b) 850°F.
(c) 1050°F.
(d) 1350°F.

28. The best bronze welding rod is one which has a content of —
(a) 60 percent zinc and 40 percent copper.
(b) 50-50 zinc and copper.
(c) 60 percent copper and 40 percent lead.
(d) 60 percent copper and 40 percent zinc.

29. In braze welding, stresses and strains caused by heating along the line of the weld may be avoided if the casting is properly —
(a) Heat-treated.
(b) Postheated.
(c) Preheated.
(d) Annealed.

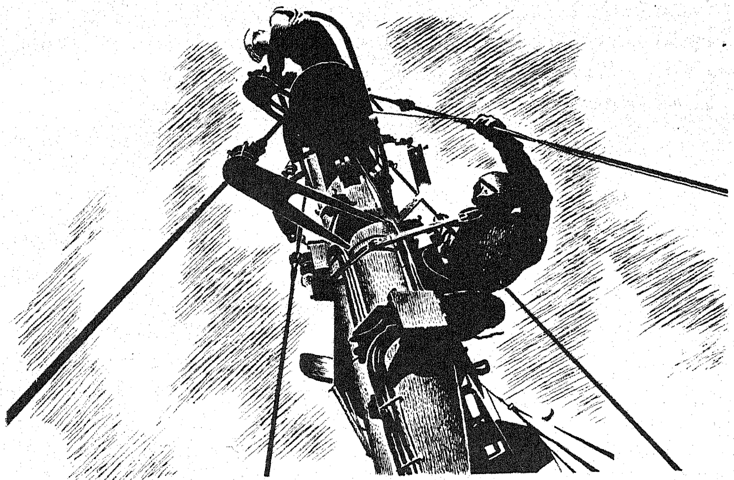
30. The type of torch flame to use for braze welding should be —
(a) Slightly reducing.
(b) Slightly oxidizing.
(c) Carburizing.
(d) Neutralizing.

31. The proper order of the steps in preparing to braze weld when preheating is necessary is —
(a) Clean, flux, aline, preheat and tin.
(b) Aline, flux, clean, tin and preheat.
(c) Clean, flux, tin, aline and preheat.
(d) Aline, clean, flux, preheat and tin.

32. During the braze welding procedure, the inner flame cone is kept away from the surface of the metal from —
(a) 0″ to ⅛″.
(b) ⅛″ to ¼″.
(c) ⅜″ to ½″.
(d) ½″ to ¾″.

33. Bright spots appearing on the braze welding puddle will indicate the—
(a) Wrong type of flame.
(b) Wrong type of rod.
(c) Lack of flux.
(d) Presence of oxides.

34. The final step of the braze welding process would be to —
(a) Quench in cold oil bath.
(b) Place in a draft of cold air.
(c) Allow to cool slowly and evenly.
(d) Place under stress immediately.



CHAPTER 8

OXYACETYLENE WELDING

The Navy thinks welding is pretty important. There's a good reason for placing this importance on welding when you consider the amount of it necessary to hold the ships, planes, machines, and the rest of the metal structures of the Navy together. You are going to do a lot of welding in the Navy, so it is important that you learn all that you can about welding and welding equipment. There's plenty of material written about welding. Your chief probably has some of the Bureau of Ships publications and a *Welder's Encyclopedia*. But if he hasn't, he can get this material through your educational officer. Read all of it that you can get your hands on, but don't ever forget that it's going to take plenty of practice to make an expert welder of you.

Now, just what is welding? It's a process of joining metal parts together while their edges are in a molten or plastic stage. The process of joining two metal parts by melting them to-

gether is called the nonpressure or fusion type of welding. Pressure processes of welding are methods of joining heated metals under impact, blows, or by pressing them together. Forge welding is one of the pressure processes. The force of the blow of the blacksmith's hammer on the heated metal applies sufficient pressure to join the parts together.

Welding processes are classified according to the method of joining and sources of heat (see figure 136). Heat for welding by the nonpressure method is most often obtained from a gas flame or an electric arc. The edges of the parts are melted together and additional metal for filling in and reinforcing the weld is melted off the end of welding rods. In some cases the weld can be made without the use of a rod.

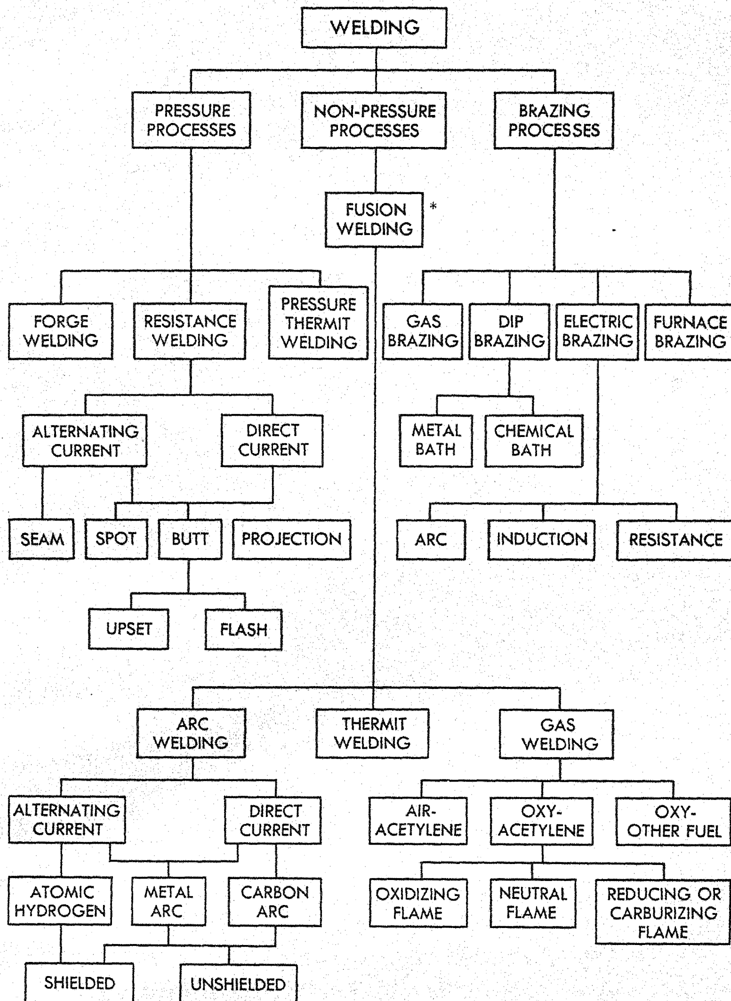
The most common of the mixtures of fuels for gas welding are oxyacetylene, air-acetylene, and oxy-other fuels. Your work will be done for the most part with the oxyacetylene welding torch.

Oxyacetylene welding is a nonpressure process in which the heat is obtained from an oxyacetylene flame formed by the combustion or burning of oxygen and acetylene. The two gases are mixed in correct proportions in a torch, which can be controlled by the operator to give any desired flame adjustment.

A good weld can be made only by taking into consideration every precaution to insure the use of proper tip size, welding rod, flame adjustment, and rod and torch manipulation. In some welding operations it is necessary to preheat. In others, you may have to cool the part slowly, and heat-treat it after welding. Still other special procedures for relieving strains and stresses may be required. In some cases, when certain metals are being welded, a flux is required to remove oxide and slag from the molten metal and to protect the puddle from contact with the air.

A properly welded joint should be uniform in appearance and in the amount of weld metal deposited. Fusion of the sidewalls is important and it should be complete to form a good joint.

In oxyacetylene welding, consideration must be given to the proper preparation of the edges of the joint, and to correct



* THIS TERM (FUSION WELDING) HAS BEEN ESTABLISHED BY LONG USAGE. IT IS RECOGNIZED, HOWEVER, THAT SOME OF THE OTHER WELDING PROCESSES INVOLVE FUSION

Figure 136.— Master chart of welding processes.

spacing and alinement of the parts so that the finished weld will have the desired appearance and shape. When sections of plate are welded, the edges of the plate at the joint must be melted down uniformly by means of proper torch movement. When welding light sheet metal, you won't need to use a filler metal or rod. You merely need to flange the edges of the sheet at the

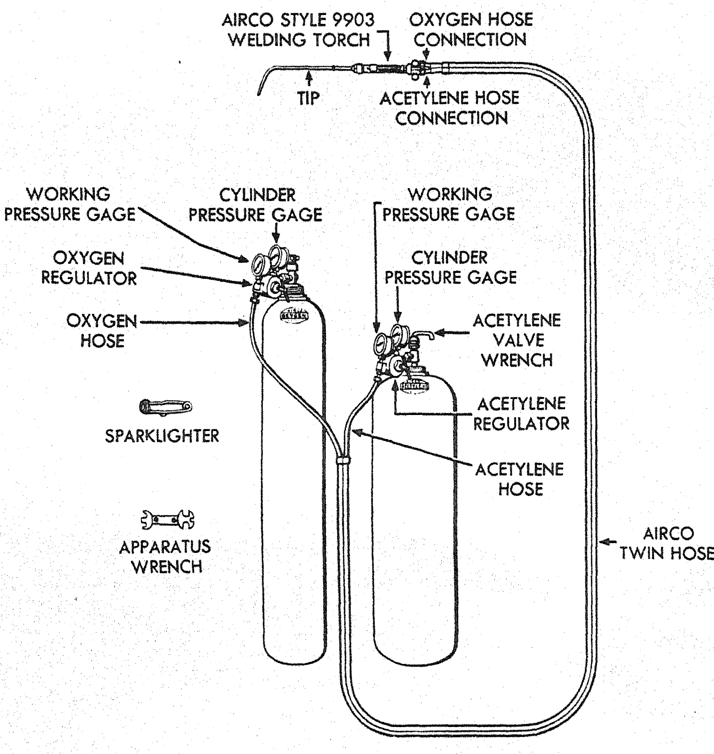


Figure 137.—Airco oxyacetylene cutting and welding outfit.

joint, and when you melt them they flow together to form one solid piece with some reinforcement. When you weld heavier sheets and plates, filler metals are required. The edges of the plate are usually beveled to permit penetration to the base of the joint. Both the filler metal and the base metal, after being melted, solidify to form one continuous piece.

OXYACETYLENE WELDING EQUIPMENT

Oxyacetylene welding equipment consists of a cylinder of acetylene, a cylinder of oxygen, two regulators, two lengths of hose with fittings, a welding torch with cutting attachments, or a separate cutting torch (see figure 137). Other requirements for getting the job done are: a spark lighter to light the torch; an apparatus wrench to fit the various connections on regulators, cylinders, and torches; suitable goggles to protect your eyes, and gloves to protect your hands (see figure 138).

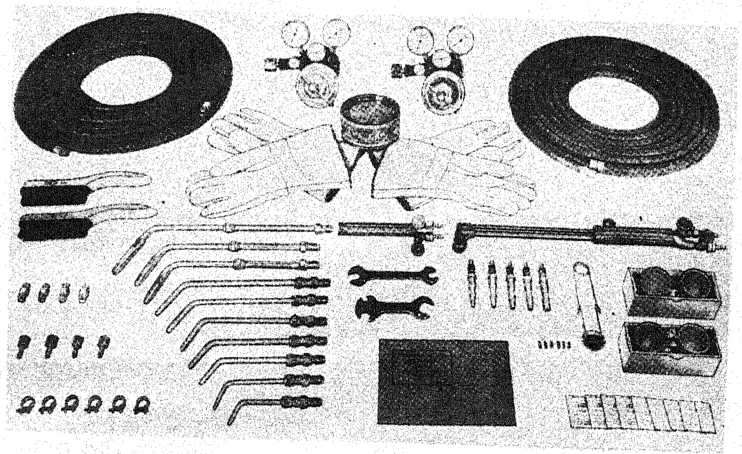


Figure 138.—Smith oxyacetylene welding and cutting outfit.

ACETYLENE

ACETYLENE is a fuel gas made up of carbon and hydrogen. Its chemical formula is C_2H_2. When burned with oxygen, acetylene produces a very hot flame. An oxidizing flame produces a temperature of approximately 6300°F. A neutral flame will give you about 5850°F., and a carburizing flame will produce a temperature of about 5700°F. (see figure 139). These temperatures are developed at the tip of the inner cone of the flame. Acetylene gas is colorless but it has an odor that is easy to recognize. Acetylene is made by the action between calcium carbide, which is a gray, stonelike substance,

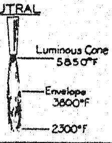
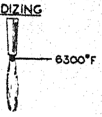
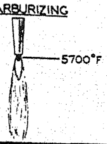
	NEUTRAL	OXIDIZING	CARBURIZING
Torch Flames	 Luminous Cone 5850°F; Envelope 3800°F; 2300°F	 6300°F	 5700°F
Ratio $\frac{\text{Oxygen}}{\text{Acetylene}}$	$\frac{1.04\text{-}1.14}{1}$	$\frac{1.15\text{-}1.70}{1}$	$\frac{0.85\text{-}0.95}{1}$
Effect on Metal	Metal is clean and clear, flowing easily.	Excessive foaming and sparking of metal.	Metal boils and is not clear.

Figure 139.—Characteristics of oxyacetylene welding flames.

and water. The gas is made with a generator which has a hopper that feeds the carbide into the water. After the gas is generated, a slaked lime is left as sludge. The acetylene that you will use will come compressed in steel cylinders, under a pressure of about 250 pounds. You may use it directly from the cylinder like the set-up in figure 137 or it may be furnished from a stationary type acetylene cylinder bank (see figure 140).

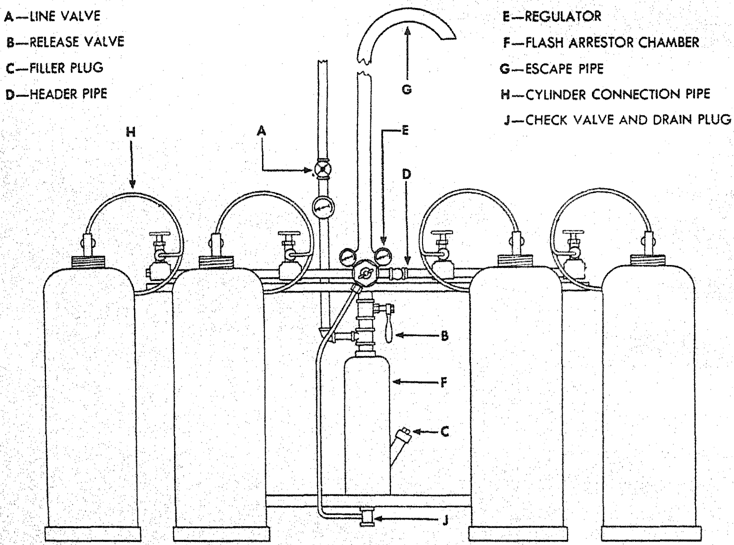


Figure 140.—Stationary type acetylene cylinder bank.

In either case, the acetylene is dissolved in acetone (a liquid) and compressed in the cylinder, which is filled with such materials as balsa wood, charcoal, finely-shredded asbestos, corn pith, Portland cement, or infusorial earth. Infusorial earth is an absorbent dirt composed of decaying vegetable and animal matter. These filler materials are porous and are used to decrease the size of the open spaces in the cylinder. This is necessary because of the danger of explosion. Pure acetylene, when stored in the free state under a pressure of 29.4 pounds per

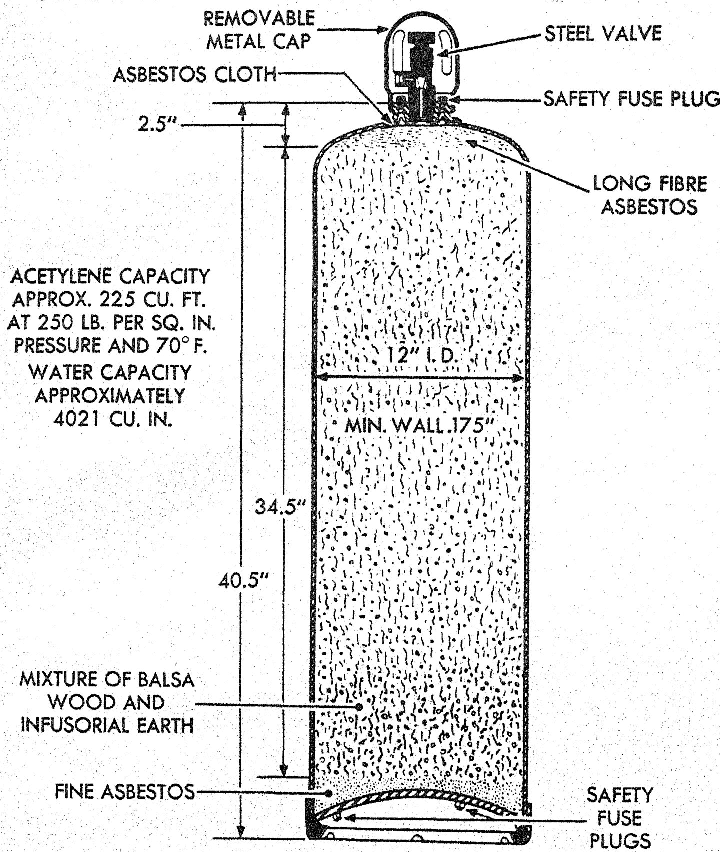


Figure 141.—Acetylene cylinder.

become liquid. The temperature is then raised to above −321° F., at which point the nitrogen becomes gas again and is removed. When the temperature of the remaining liquid is raised to −297° F., the oxygen forms gas and is taken off. The oxygen is then further purified and compressed into cylinders for use. The other process by which oxygen is obtained is known as the electrolytic process. This process consists of running an electric current through water to which an acid or alkali has been added. The oxygen collects at the positive terminal and is passed off through pipes to a container. When supplied for use in oxyacetylene welding applications, oxygen is contained in seamless steel cylinders which have a capacity of 200 cubic feet of oxygen at a pressure of 1,300 pounds per square inch and at a temperature of 70° F.

APPARATUS

REGULATORS reduce pressures and control the flow of gases from the cylinders. Regulators are either of the single-stage or of the double-stage type, depending upon the use for which they are intended. Single-stage regulators reduce the pressure of the gases in one step, while two-stage regulators perform the same work in two steps or stages. Less readjustment is generally necessary when the two-stage regulator is used. Figure 144 shows a typical single-stage regulator. The regulator mechanism consists of a nozzle through which the high-pressure

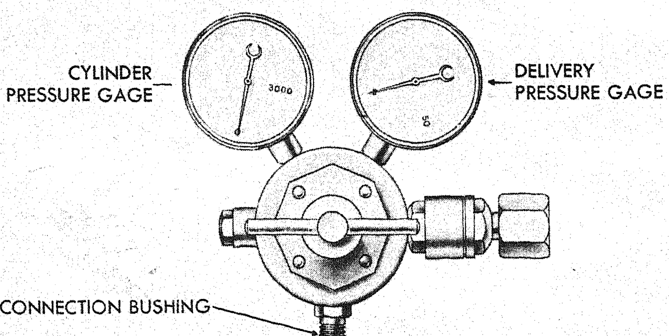


Figure 144.—Typical single stage regulator.

gases pass, a valve seat to close off the nozzle, a diaphragm, and balancing springs. These are all enclosed in a suitable housing. Pressure gages are provided to indicate the pressure in the cylinder or pipe line (inlet), as well as the working pressure (outlet). The inlet pressure gage, used to record cylinder pressures, is a high-pressure gage, while the outlet pressure gage, used to record working pressures, is a low-pressure gage. Acetylene regulators and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand such high pressures as are those designed for use with oxygen cylinders. In the oxygen regulator, the oxygen enters the regulator through the high-pressure inlet connection and passes through a glass wool filter that removes dust and dirt. Turning the adjusting screw in allows the oxygen to pass from the high-pressure chamber to the low-pressure chamber of the regulator, through the regulator outlet, and through the hose to the torch. Turning the adjusting screw to the right INCREASES the working pressure; turning it to the left DECREASES the working pressure. The high-pressure gage is graduated in pounds per square inch from 0 to 3,000 and in cubic feet from 0 to 220. This permits reading of the gage to determine cylinder pressure and cubic content. The gages are graduated to read correctly at 70°F. The working pressure gage is graduated in pounds per square inch from 0 to 50, from 0 to 200, or from 0 to 400, depending upon the purpose for which the regulator is designed. For example, on regulators designed for heavy cutting, the working pressure gage is graduated in pounds per square inch from 0 to 400.

The two-stage regulator is similar in principle to the one-stage regulator. The chief difference being that the total pressure drop takes place in two steps instead of one. In the high-pressure stage, the cylinder pressure is reduced to an intermediate pressure. In the low-pressure stage, the pressure is reduced from the intermediate pressure to a working pressure. A typical two-stage regulator is shown in figure 145.

THE OXYACETYLENE WELDING TORCH is used to mix oxygen and acetylene gas in the proper proportions and to control the volume of these gases burned at the welding tip. Torches

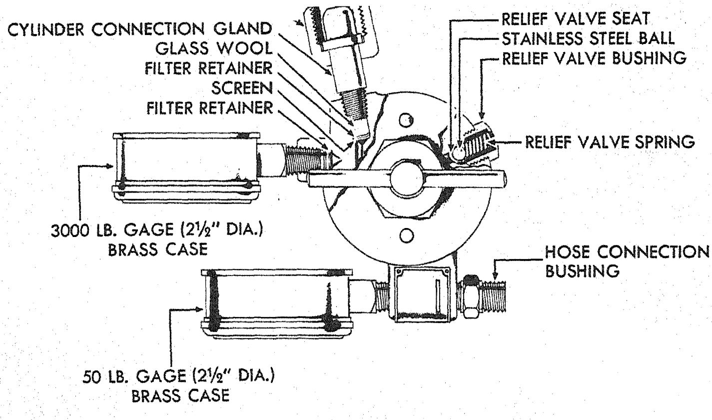


Figure 145.—Two-stage regulator.

have two needle valves—one for adjusting the flow of oxygen, and the other for adjusting the flow of acetylene. In addition, they have a handle, two tubes (one each for the oxygen and acetylene) a mixing head, and a tip. The tubes are silver soldered to the head and the rear end forgings, which are in turn fitted into the handle. Welding tips are made from copper and are available in different sizes to handle a wide range of plate thicknesses.

There are two types of welding torches. These are the low-pressure type and the medium-pressure type. In the low-pressure type, the acetylene pressure is less than one pound per square inch. A jet of high-pressure oxygen is necessary to produce a suction effect which draws in the required amount of acetylene. This is accomplished by the design of the mixer in the torch, which operates on the injector principle. The welding tips may or may not have separate injectors designed into the tip. A typical mixing head for the low-pressure or injector type of torch is shown in figure 146.

In the medium-pressure torches, the acetylene is burned at pressures from 1 to 15 pounds per square inch. These torches are made to operate at equal pressures for acetylene and oxygen. They are sometimes called equal-pressure or balanced-pressure

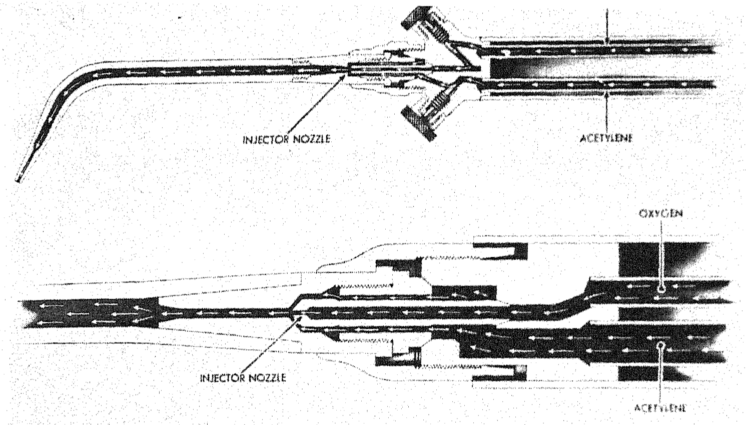


Figure 146.—Mixing head for low-pressure type torch.

torches. The medium-pressure torch is easier to adjust than the low-pressure torch, and because equal pressures are used for each torch you are less likely to get a flashback. This means that the flame is less likely to catch in or back of the mixing chamber. A typical equal-pressure type general purpose torch is shown in figure 147.

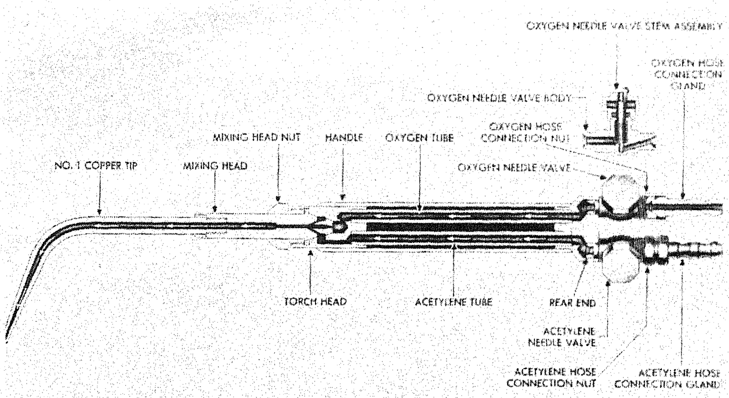


Figure 147.—Equal-pressure type general purpose welding torch.

WELDING TIPS AND MIXERS made by different manufacturers differ in design. Some makes of torches are provided with an individual mixing head or mixer for each size of tip. Other makes have only one mixer for several tip sizes. Tips come in various types. Some are a one-piece, hard-copper tip. Others are a two-piece tip that includes an extension tube to make connection between tip and the mixing head. When used with an extension tube, removable tips are made of hard copper, brass, or bronze. Tip sizes are designated by numbers and each manufacturer has his own arrangement for classifying them. Tip sizes differ in the diameter of the hole in order to obtain in each case the correct volume of heat for the work to be done.

HOSE used to make connection between the torch and the regulators is strong, nonporous, and sufficiently flexible and light to make torch movements easy. It is made to withstand high internal pressures, and the rubber used in its manufacture is specially treated to remove sulphur to avoid the danger of spontaneous combustion. Welding hose comes in various sizes, depending upon the size of work for which it is intended. Hose used for light work is $\frac{3}{16}$ or $\frac{1}{4}$ of an inch in diameter, and it has one or two plies of fabric. For heavy duty welding and cutting operations, hose with an inside diameter of $\frac{1}{4}$ or $\frac{5}{16}$ of an inch and 3 to 5 plies of fabric is used. Single hose comes in length of $12\frac{1}{2}$ feet to 25 feet. Some manufacturers make a double hose which conforms to the same general specifications. The hoses used for acetylene and oxygen are the same in grade but they differ in color. Oxygen hose is *green,* acetylene hose *red.* Other precautions to assure that you will not get the hoses mixed up are left-hand threads and grooved connection nuts on acetylene hose, and left-hand threads on fittings. All oxygen cylinder valve threads are right hand. Acetylene cylinder valve threads may be right hand or left hand, depending upon the manufacturer.

SETTING UP

SETTING UP APPARATUS AND PREPARING FOR WELDING must be done systematically and in a definite order to avoid costly mistakes. You should follow the instructions listed below, in

the order given, to assure your own safety and the safety of your equipment.

1. Secure the cylinders so that they won't be upset. Remove the protecting caps.
2. Crack the cylinder valves by opening each valve slightly for an instant to blow it out clean. Close the valves and wipe off the connections with a clean cloth.
3. Connect the acetylene pressure regulator to the acetylene cylinder and the oxygen pressure regulator to the oxygen cylinder. Use a regulator wrench and tighten the connecting nuts to prevent leakage.
4. Connect the red hose to the acetylene regulator and the [illegible] Tighten the connecting [illegible] with the oxygen in the air it produces [illegible] left-hand thread on th [illegible] inous whit [illegible]
5. Release the regulator screws to avoid abuse or damage to the regulators and gages, and open the cylinder valves slowly. Read the high-pressure gage to check the contents in each cylinder.
6. Blow out the OXYGEN hose by turning in the regulator screw, and then turn the screw back out again. If it is necessary to blow out the acetylene hose, BE SURE TO DO IT IN A WELL-VENTILATED PLACE, FREE FROM SPARKS, FLAME, OR OTHER SOURCES OF IGNITION.
7. Connect the hose to the torch. Connect the red acetylene hose to the connection gland that has the needle valve marked *AC*, and the green oxygen hose to the connection gland having the needle valve stamped *OX*. Test all hose connections for leaks by turning in both regulator screws with the needle valves closed. Turn out the regulator screws and drain the hose by opening the needle valve.
8. Adjust the tip. Screw the tip into the mixing head and assemble in the torch body. Tighten by hand and adjust to the proper angle. Secure this adjustment by tightening with the wrench provided with the torch.
9. Adjust the working pressures. The acetylene working pressure is adjusted by opening the acetylene torch needle

valve and turning the regulator screw to the right. Adjust the acetylene regulator to the required working pressure for the particular tip size as follows:

WORKING PRESSURES FOR OXYGEN AND ACETYLENE

Low-Pressure or Injector Type of Torch

TIP SIZE NO.	ACETYLENE PRESSURE LBS. PER SQ. IN.	OXYGEN PRESSURE LBS. PER SQ. IN.
0	1	9.
1	1	9.
2	1	10.
3	1	10.
4	1	11.
5	1	12.
6	[illegible]	[illegible]
7	[illegible]	[illegible]
8	[illegible]	19.
10	1	21.
12	1	25.
15	1	30.

Medium-Pressure or Balanced-Pressure Type of Torch

TIP SIZE NO.	ACETYLENE PRESSURE LBS. PER SQ. IN.	OXYGEN PRESSURE LBS. PER SQ. IN.
00	1	1.
0	1	1.
1	1	1.
2	2	2.
3	3	3.
4	4	4.
5	5	5.
6	6	6.

10. Light off and adjust the welding tip. Open the acetylene needle valve on the torch and light the acetylene with a spark lighter. Keep your hand out of the way. Adjust the acetylene valve until the flame just leaves the tip face. Open and adjust the oxygen valve until you get the proper neutral flame. Notice that the pure acetylene flame which just leaves the tip face is drawn back to the tip face when the oxygen is turned on.

A pure acetylene flame is long and bushy and has a yellowish color. It is burned by the oxygen in the air, which is not sufficient to burn the acetylene completely; therefore, the flame is smoky, producing a soot of fine, unburned carbon. The pure acetylene flame is unsuitable for welding. When the oxygen valve is opened, the mixed gases burn in contact with the tip face. The flame changes to a bluish-white color and forms a bright inner cone surrounded by an outer flame-envelope. The inner cone develops the high temperature required for welding.

There are three types of flame commonly used for welding. These are neutral, reducing or carburizing, and oxidizing flames (see figure 116). The NEUTRAL flame is produced by burning one part of oxygen to one part of acetylene. Together with the oxygen in the air it produces complete combustion of the acetylene. The luminous white cone is well-defined and there is no greenish tinge of acetylene at its tip, nor is there an excess of oxygen. The welding flame should always be adjusted to neutral before either the oxidizing or carburizing flame mixture is set. A neutral flame is obtained by gradually opening the oxygen valve to shorten the acetylene flame until a clearly defined inner luminous cone is visible. This is the correct flame to use for many metals. It is used for most welding and for the preheating flames during cutting operations. The temperature at the tip of the inner cone is about 5850°F., while at the extreme end of the outer cone it is only about 2300°F. This gives you a chance to exercise some temperature control by moving the torch closer or farther from the work. When steel is welded with this flame, the puddle of molten metal is quiet and clear, and the metal flows without boiling, foaming, or sparking.

THE CARBURIZING FLAME is produced by burning an excess of acetylene. You will be able to recognize it by the feather at the tip of the inner cone. At the end of the inner cone, this feathery tip has a greenish color. The degree of carburization can be judged from the length of the feather. For most welding operations the length of the feather should be about twice the length of the inner cone. You can always recognize the car-

burizing flame by its three distinct colors. These are the bluish-white inner cone, a white intermediate cone, and the light-blue outer flame. The carburizing flame burns with a temperature of about 5700° F. at the tip of the inner cone. When it is used for welding steel, the metal boils and is not clear. A carburizing flame is best for welding high-carbon steels, for hard-facing, and for welding nonferrous alloys such as monel.

THE OXIDIZING FLAME is produced by burning an excess of oxygen. You can identify this flame by the shorter outer flame and the small, white, inner cone. It takes about two parts of oxygen to one part of acetylene to produce this flame, and you will find that the adjustment for the oxidizing flame is a bit more difficult to make than the adjustment for other flames. To adjust for the oxidizing flame, first adjust to a neutral flame and then open the oxygen valve until the inner cone is about one-tenth of its original length. An oxidizing flame makes a hissing sound, and the inner cone is somewhat pointed and purplish in color at the tip. The oxidizing flame has a limited use and is harmful to many metals. When it is applied to steel, the oxidizing flame causes the molten metal to foam and give off sparks. This means that the extra amount of oxygen is combining with the steel, causing the metal to burn. However, the oxidizing flame does have its uses. A slightly oxidizing flame is used in bronze welding of steel and cast iron, and a stronger oxidizing flame is used for fusion welding of brass and bronze. You will have to determine the amount of excess oxygen to use in this type of flame adjustment by watching the molten metal. Experience is the best teacher.

OXYACETYLENE WELDING METHODS AND POSITIONS

You will discover by practice the method of oxyacetylene welding best adapted to you. There are several methods that may be used that will produce good results. If you are right-handed you will probably hold the torch in the right hand and the rod in the left. But if you are a southpaw, you will probably hold the torch in the left hand and the rod in the right. You

may find it easier to weld from left to right or in the opposite direction. The best method to use depends upon the type of joint, its position, and the necessity for controlling the heat on the parts to be welded. Use the method that seems most natural to you, but if you can imitate your chief or first class, you'll save yourself a lot of time.

FOREHAND, PUDDLE, or RIPPLE WELDING is the oldest method of welding. The rod is kept ahead of the tip in the direction in which the weld is being made. Point the flame in the direction of the welding and hold the tip at an angle of about 60° to the plates you are welding (see figure 148). This position of the flame preheats the edges you are welding just ahead of the molten puddle. By moving the tip and welding rod back and forth in opposite, semicircular paths, you balance the heat to melt the end of the rod and the sidewalls of the joint into a uniformly distributed molten puddle. As the flame passes the rod it melts off a short length of the rod and adds it to the puddle. The motion of the torch distributes the molten metal evenly to both edges of the joint and to the molten puddle. This method is used for welding sheets and light plates in all positions. It is not the best method for welding heavy plate, as a wide V 90° included angle of bevel is necessary.

BACKHAND WELDING is the newer method of welding. In this method the torch tip precedes the rod in the direction of welding, and the flame is pointed back at the molten puddle and the completed weld. The end of the rod is placed between the torch tip and the molten puddle, and the welding tip should make an angle of about 60° with the plates or joint being welded (see figure 149).

Less motion is required in the backhand method than in the forehand method. If you use a straight welding rod, it should be rotated so that the end will roll from side to side and melt off evenly. You may also bend the rod and, when welding, move the rod and torch back and forth at a rather rapid rate. If you are making a large weld, you should move the rod so as to make complete circles in the molten puddle. The torch is moved back and forth across the weld while it is advanced slowly and uniformly in the direction of the welding. You'll find the

backhand method best for welding heavy plate. You can use a narrower V at the joint than is possible in forehand welding. An included angle of 60° is sufficient angle of bevel to get a good joint. It doesn't take so much welding rod or so much puddling for the backhand method as it does for the forehand method.

MULTILAYER WELDING is used in welding thick plate and pipe in order to avoid carrying too large a puddle of molten metal, which is difficult to control. You can concentrate on getting a good weld at the bottom of the V in the first pass. Then in the next layers you can concentrate on getting good fusion with the sides of the V and the previous layer. The final layer is easily controlled to get a smooth surface. This method of welding has an added advantage in that it refines one layer as the succeeding layer is made. In effect, it heat-treats the weld metal by allowing one layer to cool to a black heat before it is reheated. This improves the ductility of the

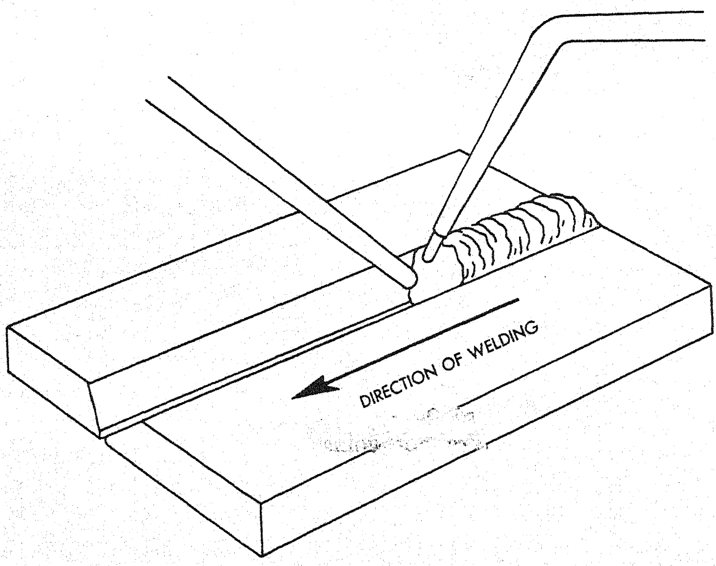


Figure 148.— Forehand, puddle or ripple welding.

weld metal. If this added quality is desired of the last layer, an additional or succeeding layer is deposited and then machined off smooth.

All welding is done in one of four positions. These are: FLAT, VERTICAL, OVERHEAD, and HORIZONTAL. The flat position is the easiest for you to start on.

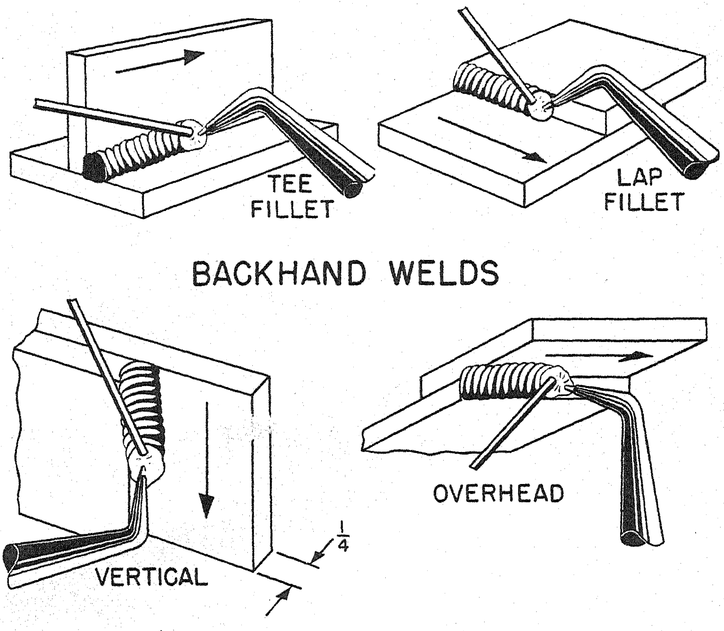


Figure 149.—Backhand welding.

Running a bead without a filler in the flat position should be your No. 1 job. A bit of help and supervision from a rated Metalsmith is a MUST on your first welding job. Take a look at figure 150. You're not going to weld two pieces together in a job like this; but you're just going to run a bead. Select a piece of stock ⅛ by 2 by 4 inches. Place this piece on two firebricks so that the part to be heated will not contact the bricks. Use a No. 2 torch tip. Adjust the flame to neutral or slightly carburizing. Avoid an oxidizing flame. Don't forget your goggles and gloves. If you are right-handed,

start at the right and work to the left. Hold the torch tip so that it makes an angle of 90° across the line of the weld. Direct the inner cone of the flame at a point near the right edge of the metal and hold it there until a molten puddle forms. Keep the tip of the cone from 1/16 to 1/8 inch away from the surface of the molten metal. As soon as your puddle is formed, move the torch slowly forward with the weaving motion shown in figure 150. Both the forward motion and the weaving motion

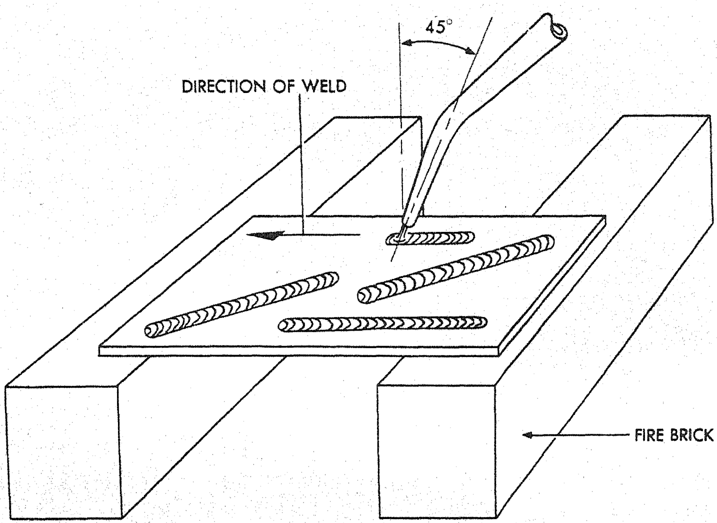


Figure 150.—Running a bead without a filler.

must be uniform if you are to get a smooth, regular bead. A good bead weld must have a uniform width of weld face, a surface of weld slightly below the surface of the base metal, and a thin film of oxides on the surface of the weld. The speed with which the flame is carried along the plate should be regulated to get good fusion without burning through. When you think you are pretty good, try a thinner piece of stock. A bead without filler can be used to weld an edge like the one in figure 151. Just tack-weld the ends by fusing them together and if you are right-handed, start a puddle at the right and run your weld to the left.

RUNNING A BEAD IN THE FLAT POSITION WITH ADDED FILLER METAL is the next step in welding. This job is very similar to the first job you tackled. In this job the bead is built up by adding filler metal (welding rod). Use a $\frac{3}{32}$-inch mild steel rod. The weld should be built up about 25 percent or an amount equal to one fourth the thickness of the stock. Start the puddle and as soon as it is formed add the end of the welding rod to the middle of it. Keep the inner cone of the flame weaving. The movement of the rod should be opposite to that of the flame. When the flame is on one side of the puddle, the rod should be on the other side. Stir the end of the rod in the puddle, not above it. Do not direct the flame at the end of the rod. Let the puddle melt it. Direct the flame so that it preheats the weld area uniformly, or you won't get good fusion. If you hold and manipulate your torch and rod just right, you should get a job like the one shown in figure 152.

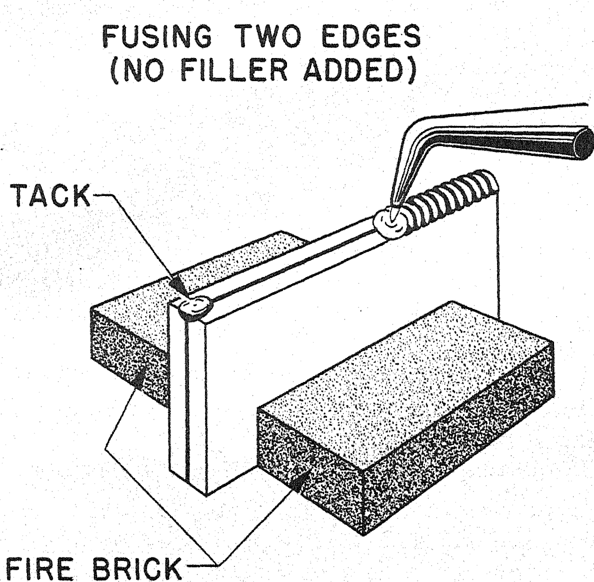


Figure 151.—Fusing edges without added filler.

There are five basic TYPES OF WELDED JOINTS. These are the BUTT, LAP, T-, CORNER, and EDGE joints (see figure 154).

The butt joint is used to join the ends or edges of two plates or surfaces located in the same plane with each other. Edges for butt welds can be prepared by flame cutting, shearing,

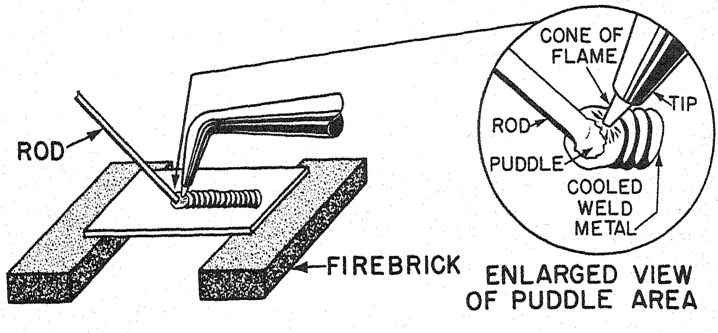


Figure 152.—Adding filler metal in the flat position.

Incorrect torch manipulation will cause UNDERCUTTING and OVERLAPPING (see figure 153).

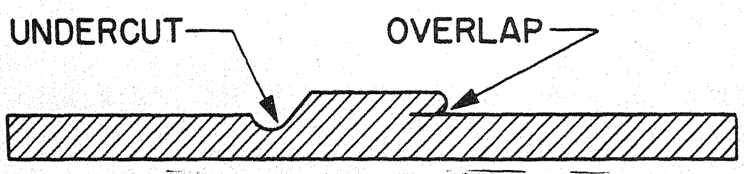


Figure 153.—Undercut and overlap.

flame grooving, machining, chipping, or grinding. The edge surfaces should in either case be free of oxides, scale, dirt, grease, or other foreign matter. The types of welds applicable to butt joints are (see figure 155):

1. Square groove.
2. Single-V groove.
3. Double-V groove.
4. Single bevel groove.
5. Double bevel groove.
6. Single-U groove.
7. Double-U groove.
8. Single-J groove.
9. Double-J groove.

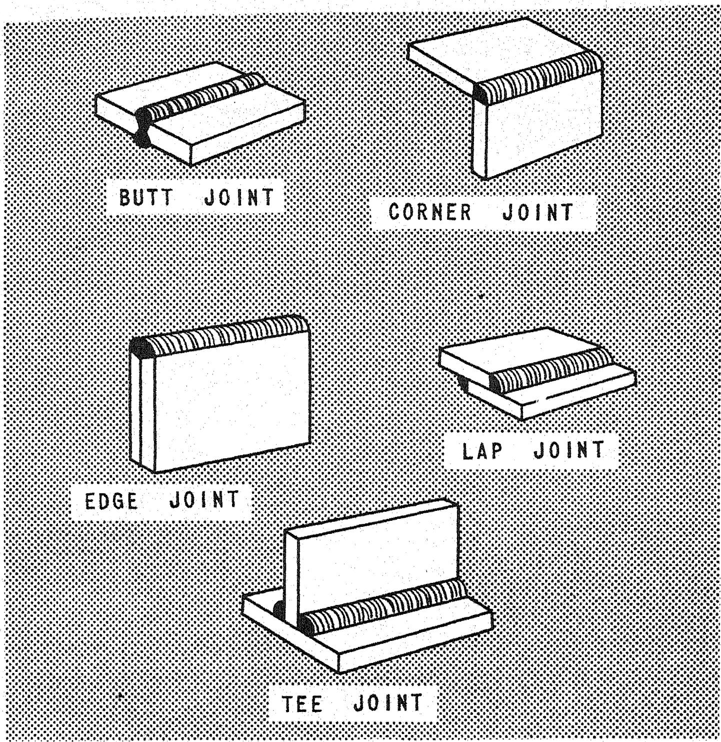


Figure 154.—Types of welded joints.

Plate from 3/8 to 1/2 inch can be satisfactorily welded from one side only, but heavier sections should be welded by preparing the edges from both sides. Generally, butt joints prepared from both sides permit easier welding, produce less distortion, and insure better weld-metal qualities in heavy sections than joints prepared from one side only. Butt welding in the flat position is used a lot on sheet metal. To do the job, tack the two pieces of sheet together leaving a gap of 1/16 inch. Be sure that your flame is correctly adjusted to a neutral or slightly carburizing flame. Let the tacks cool and then start a puddle at the end from which you work. This is where you really

begin to learn about fusion and penetration. Both have to be just right to get a good weld. The position of your torch and rod are most important in making a good butt joint in the flat position. Study these positions shown in figure 156.

Hold the welding tip at an angle of 45° to the base plate

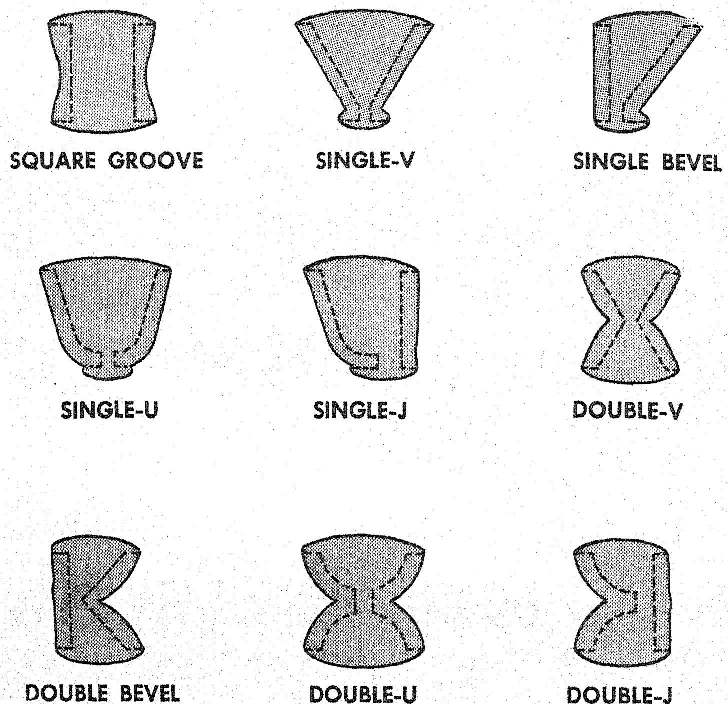


Figure 155. — Groove welds.

Control the flame so as to melt or break down the sidewalls of the stock as well as to melt enough of the welding rod to produce a puddle of the desired size. If you weave the welding tip and the rod in the right direction, you can carry along a

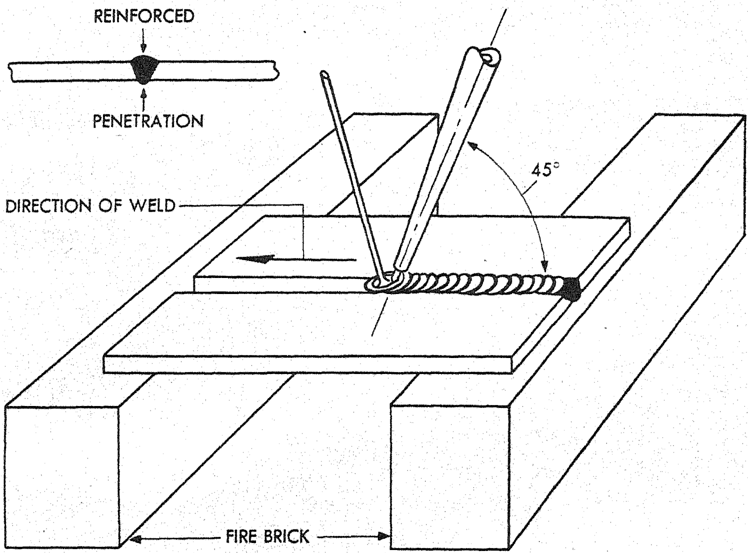


Figure 156.—Position of the rod and torch in making a butt joint in the flat position.

molten puddle that will give you complete penetration and enough filler metal to reinforce the weld. Be especially careful not to overheat the molten puddle, as it will result in burnt metal and low strength in the completed weld.

To RUN A BEAD WELD IN VERTICAL POSITION, you have the problem of keeping the molten metal from running down and piling up. To control the flow of the molten metal, hold your flame below your welding rod, pointing upward at an angle of 45° to the stock. The gas pressure from the torch will support the molten metal and distribute it evenly along the joint. If you will bend your welding rod at an angle of 90° a short distance from the end, it will be easier to add filler metal to the joint.

BUTT JOINTS welded in the VERTICAL POSITION should be prepared for welding like butt joints welded in the flat position. Take a look at figure 157 and check the position of the torch tip and welding rod.

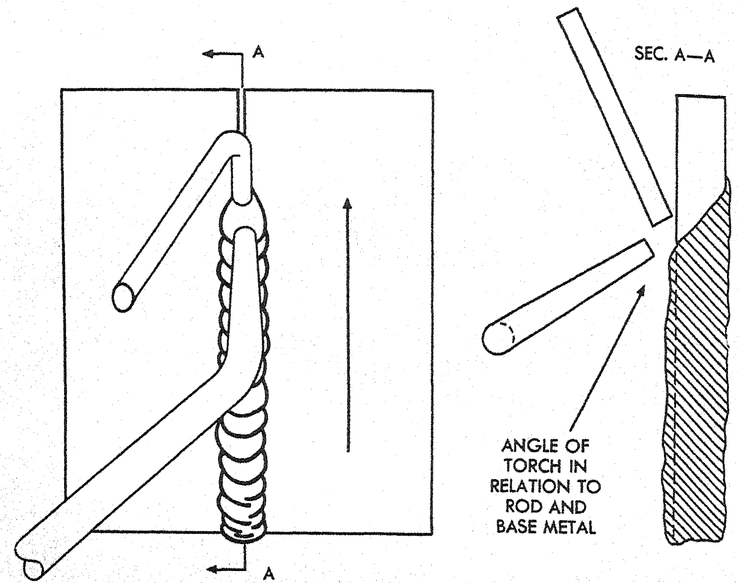


Figure 157.— Welding a butt joint in the vertical position.

In making a butt joint in the vertical position in plate, the sidewalls must be melted and sufficient filler metal added by melting the welding rod. You'll need to incline the tip at an angle of 45°, directing the flame upward to keep the molten metal from sagging.

TO RUN A BEAD WELD IN THE OVERHEAD POSITION you'll have to overcome the tendency of the molten metal to drop down or sag on the plate. This causes the bead to have a slight crown. Keep your puddle small to overcome this difficulty, and add enough filler metal to get good fusion with some reinforcement at the bead. If your molten puddle gets too large, take the flame away for an instant to allow the metal to freeze before going on with the welding. When you are welding light sheets,

you'll find that the best method is to apply heat equally to the base metal and the filler rod to control the size of the puddle.

A BUTT JOINT IN THE OVERHEAD POSITION is shown in figure 158. Direct the flame so as to melt both edges and add enough filler metal to keep the puddle at the right size and give ample

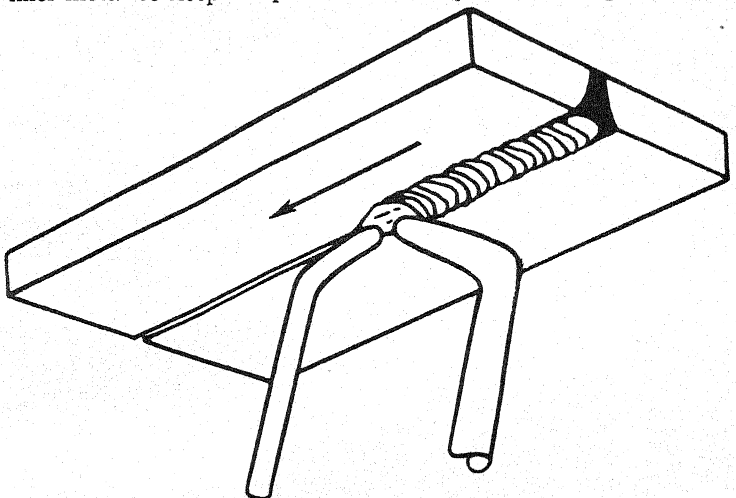


Figure 158.— Welding a burt joint in the overhead position.

reinforcement. You'll have to watch the position of the flame so that it will support the molten metal and distribute it along the joint. Don't use too large a welding rod, as you will have to keep a small puddle. Watch your heat to see that it is distributed evenly, so you won't burn through the plate. This is especially important when the welding can be done from but one side.

A BUTT WELD IN THE HORIZONTAL POSITION ON A VERTICAL FIXED PIPE is one of the toughest jobs that you will run into. Bevel the joint to 30° and tack-weld it in four places. Hold the torch so that the flame points slightly upward. Use the back-hand method. Start at a tack and carry the weld completely around the pipe. When you have mastered the horizontal weld on a vertical pipe, you can start calling yourself a welder. After that you won't have to worry about passing welding tests for Metalsmith 3 and 2.

You have seen how the BUTT JOINT may be used in the four positions. Now the other types of joints (see figure 154) you'll remember are the corner, edge, lap, and **T**-joint.

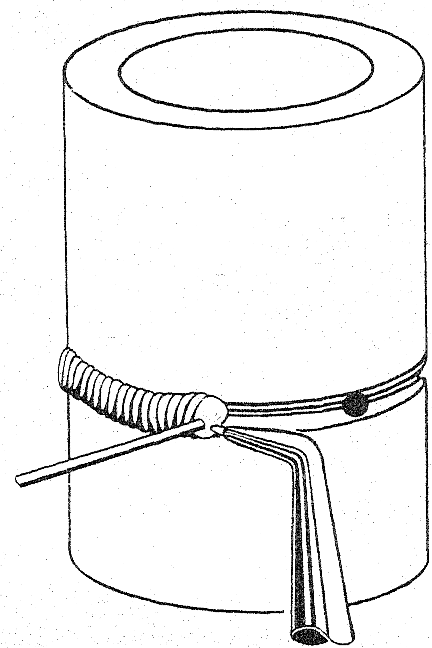


Figure 159.—Horizontal weld on vertical fixed pipe.

The CORNER JOINT is used to join the edges of two plates, the surfaces of which are at an angle of 90° to each other. The corner joint shown in figure 154 is used in making box frames, tanks, boxes, and similar articles. You can weld from one or both sides, depending upon the position and the type of corner joint used. Figure 160 shows you some of the more common types of joint designs used in making corner joints.

In figure 160, *A* is a closed-type corner joint used on lighter sheets and plates, where the strength at the joint is not required to be too great. To make the joint, melt the overlapping edge with the torch and add only a small amount of filler metal to make the joint. When you are welding heavy sections,

V-bevel or *U*-groove the lapped plate to permit penetration to the root of the joint. *B* shows an open-type corner joint which you'll use on heavier sheet and plate. Melt down the two edges of the plate and add enough filler to build up the corner from one side. *C* is an open corner joint used with heavy plate and welded from both sides. You first weld the joint from the outside and then reinforce it from the back side with a seal bead.

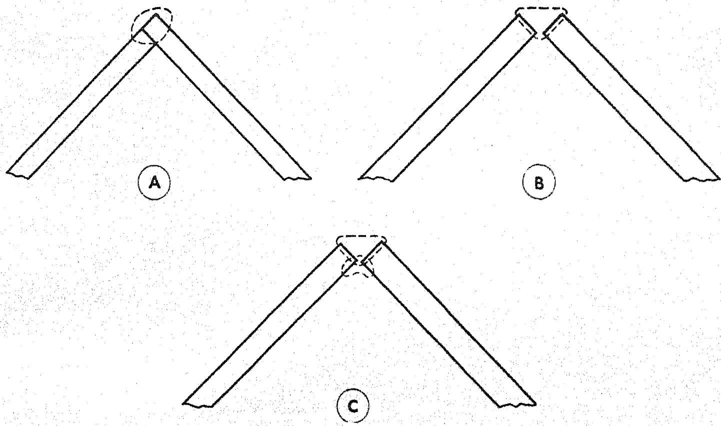


Figure 160. — Types of corner joints for sheet and plate.

The EDGE JOINT which you'll remember as one of your first jobs, is used mainly to join the edges of sheet metal and to weld reinforcing plates on flanges of I-beams or edges of angles. Enough filler metal has to be added to fuse both edges and reinforce the joint. Figure 161 shows two common types of edge joints. *A* is used for welding thin sheets. You won't have to prepare the edges in this type of joint except for cleaning and tacking them together. The joint shown in *B* is used for heavy plate. You'll have to bevel the edges in this type of joint to get good depth of penetration and fusion of the sidewalls.

The LAP JOINT IS used to weld two sections of plate so that each section of plate is welded to the other plate. If the design of the joint won't permit you to weld from both sides, you can make the joint by welding one side only. A joint weld on one side only, however, doesn't develop its full strength, but it is

stronger than a butt joint in some places. Tubing or frames that overlap or telescope together are cases where lap joints are better than butt joints.

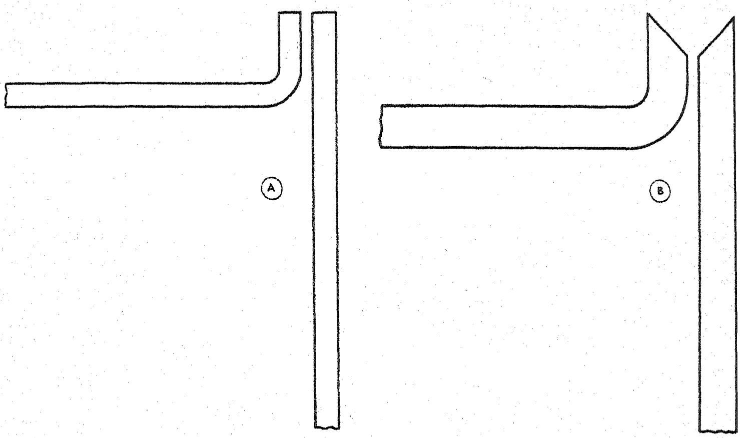


Figure 161.—Edge joints for sheet and plate.

The T-JOINT is used to weld two sections of plate when the surfaces are required to be at an angle of 90° to each other. A plain T-joint like the one in figure 154 requires little preparation; but for thicker plate, special preparation is required (see figure 162).

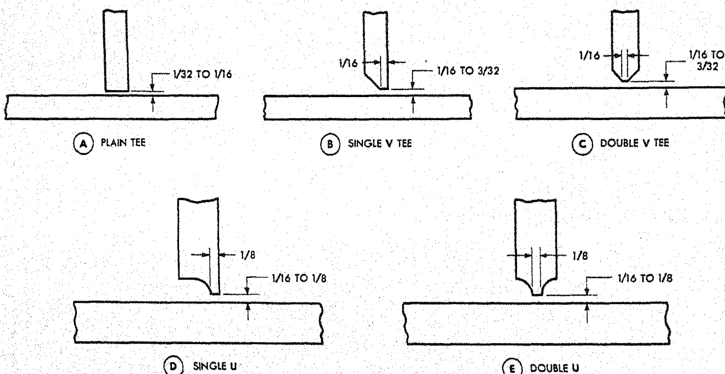


Figure 162.—Preparation of metals for welding T-joints.

CONTROL OF EXPANSION AND CONTRACTION

You know that when a metal is heated it expands and when it cools it contracts. In other words, its dimensions increase when it is heated, and they decrease when the metal is cooled. The high temperatures required for welding cause a lot of trouble in the form of warping, knuckling, and other forms of distortion. Figure 163 shows how distortion may occur if it is not allowed for or controlled.

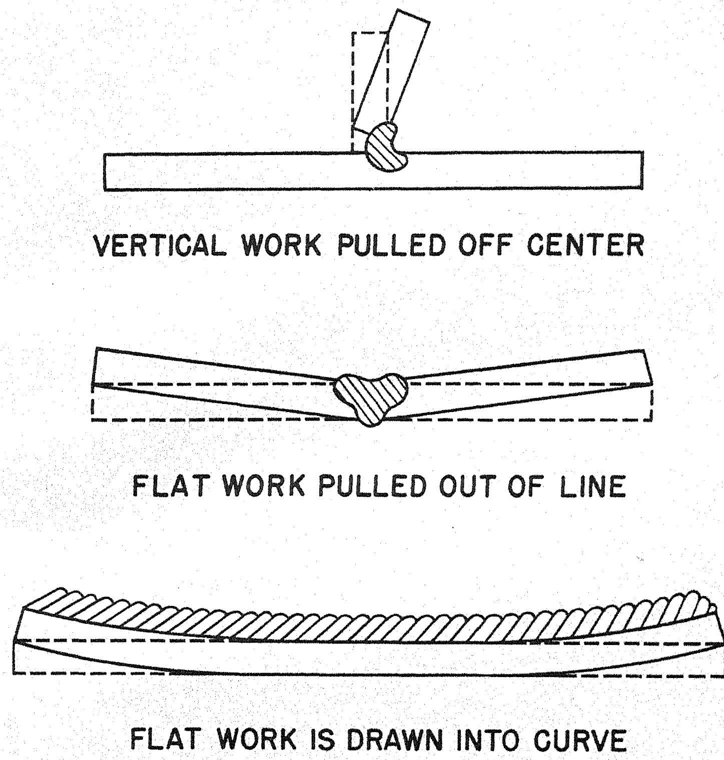


Figure 163.—Distortion caused by heating and cooling.

TACK-WELDING helps a lot in preventing undue distortion. You'll usually tack-weld sheet metal joints at short intervals.

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Most joints can be alined and held in place with pieces of angle iron and C-clamps. Special clamps and jigs may have to be made up for some jobs. On a straight butt-welded seam you can make allowances for distortion by spacing the edges as shown in figure 164. The usual allowance for steel is $\frac{1}{2}$ inch per lineal (running) foot. As the weld metal cools behind the puddle, it will contract and pull the edges into the proper position. A wedge may be used to keep a long joint open for welding. Keep the wedge approximately 18 inches ahead of the weld. (See figure 165.)

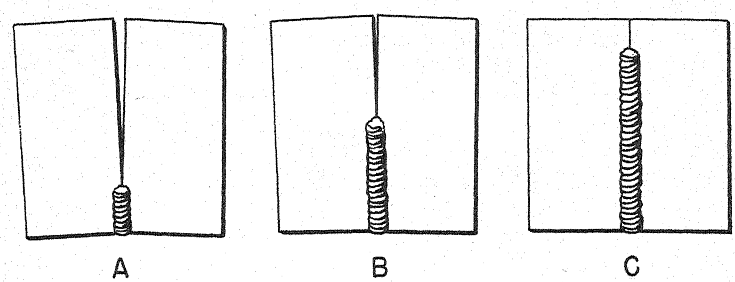


Figure 164.—Allowance for straight butt weld.

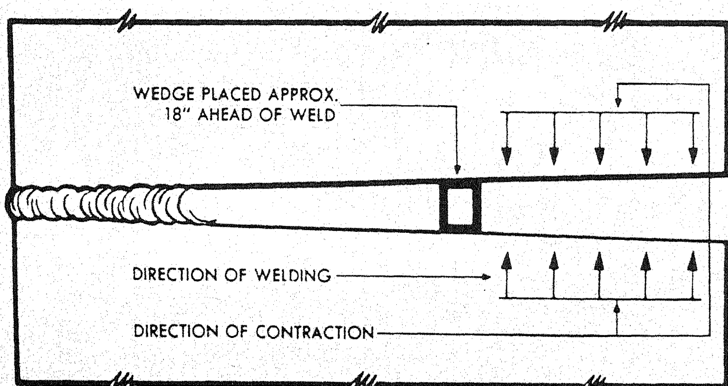


Figure 165.—Keeping the joint open with a wedge.

In addition to the simple expansion and contraction encountered when heating and cooling metal, there are certain internal stresses and strains set up by the heating and cooling process. These may be powerful enough to cause a break in the weaker portions of the metal. Even if there is no break there is always that internal stress left as a result of heating if the metal is improperly treated. To minimize these internal stresses and strains, either the stagger method of welding, or the backstep method of welding may be used. Preheating and postheating are also important in the removing of internal stresses.

BACKSTEP WELDING is simply a method of welding one section of the joint at a time in the opposite direction from the general direction of the welding. This method directs the heat on the weld away from the open end of the joint. Of course you will have to clean each section as you go along, and the method is slower than running an ordinary bead weld. You will find this method especially useful in the welding of long joints (see figure 166).

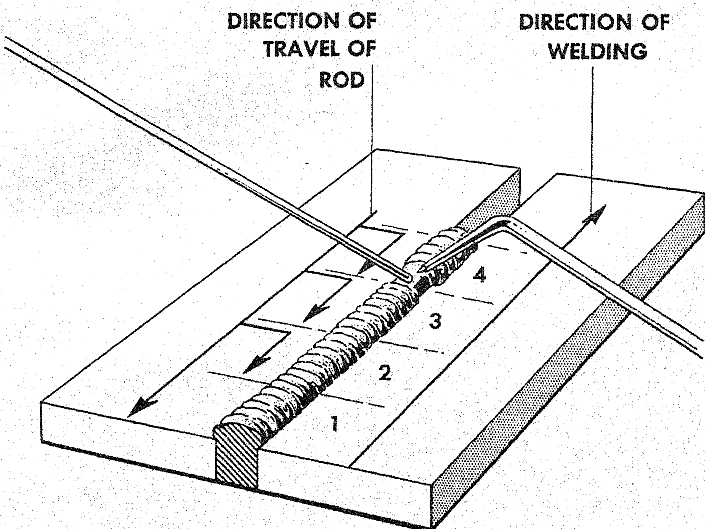


Figure 166.—Backstep method of welding.

THE STAGGER METHOD of welding is no different from other types of welding that you have done except that instead of running a continuous bead from one end of the joint to the other, you weld separate sections leaving a gap along the joint (see figure 167). Then you go back and fill in the gaps.

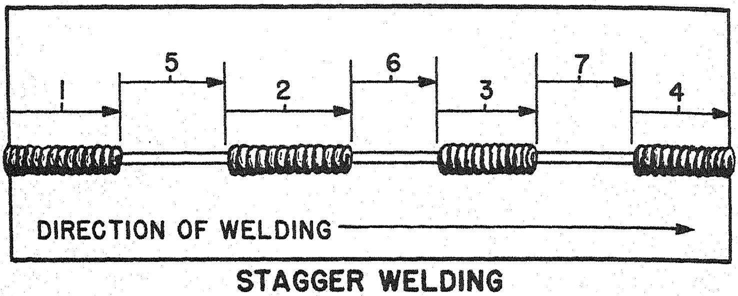


Figure 167.—Stagger welding.

PREHEATING may somewhat control expansion and contraction in castings. Before you weld small gray iron castings, you should preheat them with your torch to a very dull red heat visible in a darkened room. After you weld the castings, reheating and slow cooling—annealing—will relieve all internal stresses and assure a proper gray iron structure. For larger castings, you may have to construct a temporary furnace of firebrick covered with asbestos sheet. Quite often only local preheating of the part next to the weld will do the job. Your Hauck Burner, gasoline torch, or your acetylene torch may be used for this purpose. Before you weld a crack that runs from the edge of a casting, you will do well to drill a hole about ¾ inch from the end of the crack. Then if the crack starts to run when the heat is applied, it will run only as far as the hole. The same methods that apply to gray iron castings will apply to steel castings or castings to be bronze-welded, except that you need less preheat. Some methods are shown in figure 168 for expanding castings before welding when it is not convenient or practical to preheat them all over.

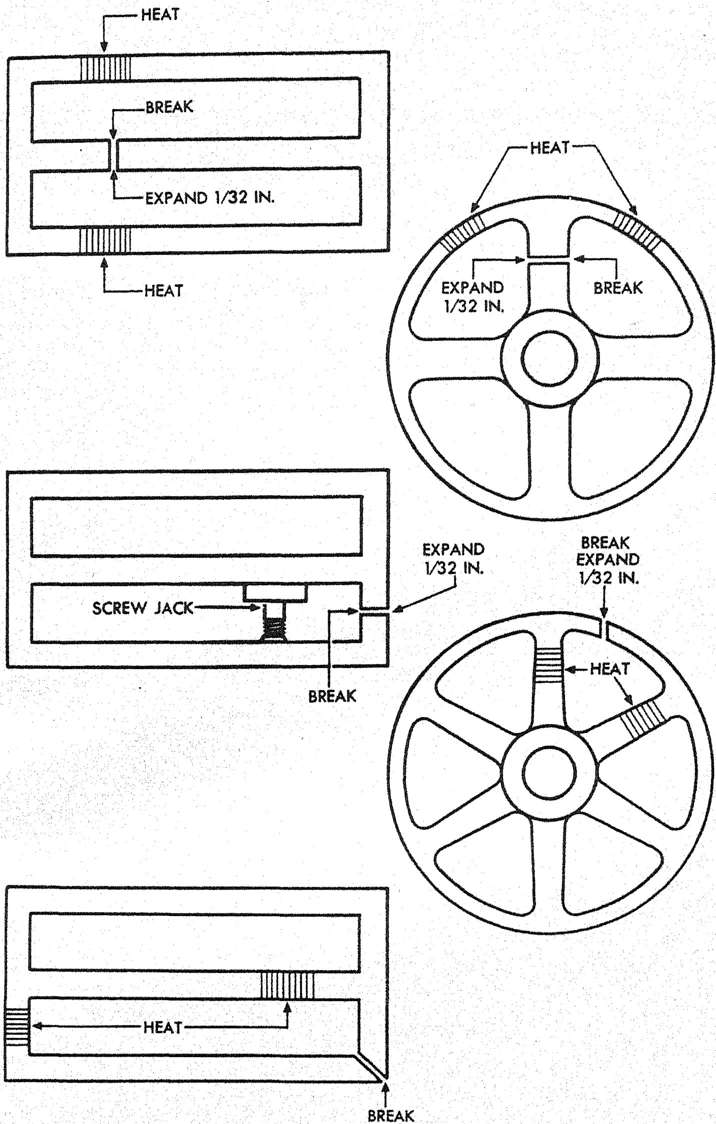


Figure 168.—Controlling expansion by spot preheating.

There are a lot of things that you will have to know and remember to do a good job of welding. Some of these you will have to learn the hard way. Others you can pick up from such sources as the following chart:

GUIDE FOR OXYACETYLENE WELDING

Ferrous Metals

Metal or Alloy	Flame Adjustment	Rod	Flux	Preheating	Precautions and Stress Relieving
Low-carbon steel to .30% C.	Neutral to Sl. Carburizing	Copper coated low-carbon	None	Remove chill	None.
Medium-carb. steel .30-.50% C.	Sl. Carburizing	Low-carb. or high strength	None	300°-500° F.	Cool slowly with asbestos.
High-carb. steel .50-.90% C.	Carburizing	High-carbon	None	500°-800° F.	1200°-1450° F. Postheat.
Tool steel	Carburizing	Drill rod	Some C. I.	Up to 1000° F.	Heat-treat.
Cast steel, plain carbon	Neutral	Low-carbon	None	200° F.	Cool slowly with asbestos.
Cast steel, high manganese	Sl. Carburizing	Nickel Mang. steel	Wrap rod w/al. wire	None	Cool slowly with asbestos.
Stainless steel	Neutral	Same as base metal stainless	Stainless	None	Cool quickly.
Low-alloy high-tensile steels	Neutral to Sl. Carburizing	Same as base or high strength	None	Yes up to 1100° F.	Heat-treat.
Wrought iron	Neutral	Low-carbon or high strength steel	None	None	Heat-treat.
Low-carbon iron	Neutral	Low-carbon	None	None	Heat-treat.

Gray cast iron	Neutral	Cast iron	Cast iron flux	700°-800° F.	Cool slowly.
Malleable iron	Neutral	White cast iron	Cast iron flux	700°–800° F.	Heat-treat to remalleablize.
Alloy cast irons	Neutral	Same as base metal or C. I.	Cast iron flux	500°-1000°F.	Postheat and cool slowly.

Nonferrous Metals

Metal or Alloy	Flame Adjustment	Rod	Flux	Preheating	Precautions and Stress Relieving
Copper	Sl. oxidizing	Same as base metal	None	500°–800° F.	Cover and cool slowly.
Brass	Oxidizing	Base metal or bronze	Brazing	200°–300° F.	Postheat; cool slowly.
Bronze	Oxidizing	Same as base metal	Brazing	200°–300° F.	Postheat; cool slowly.
Aluminum alloy	Neutral	95% aluminum and 5% silicon	Aluminum	500°–800° F.	Normal air cool.
Nickel	Carburizing	Nickel	None	200°–300° F.	Postheat; cool slowly.
Monel	Carburizing	Monel	Brazing	200°–300° F.	Postheat; cool slowly.
Inconel	Carburizing	Inconel	Brazing	200°–300° F.	Cool slowly.
Lead	Neutral to Sl. Carburizing	Lead	Soldering acid	None	Normal cooling.
Magnesium alloy	Sl. Carburizing	Same as base metal	Special	500°–600° F.	Normal cooling.

QUIZ

Select the one best answer to each of the following statements.

1. Acetylene is a compound of—
   (*a*) Illuminating gas and oxygen.
   (*b*) Oxygen and carbon.
   (*c*) Carbon and hydrogen.
   (*d*) Calcium and illuminating gas.

2. Acetylene cylinders are frequently charged to pressures as high as—
   (*a*) 250 p.s.i.
   (*b*) 500 p.s.i.
   (*c*) 750 p.s.i.
   (*d*) 1000 p.s.i.

3. The material used to dissolve free acetylene for compression into the acetylene cylinder is—
   (*a*) Acetone.
   (*b*) Amyl alcohol.
   (*c*) Carbon disulfide.
   (*d*) Cotton.

4. Precautions shall be taken in handling acetylene cylinders to prevent dropping or subjecting to other shocks or blows because they are —
   (*a*) Highly explosive.
   (*b*) Easily damaged.
   (*c*) Extremely fragile.
   (*d*) Highly volatile.

5. The best test for acetylene leaks is the use of—
   (*a*) An open flame.
   (*b*) Soapy water.
   (*c*) Compressed air.
   (*d*) Test paste.

6. An oxygen regulator is used to—
   (*a*) Adjust the flow of oxygen from the torch.
   (*b*) Reduce the cylinder pressure to working pressure.
   (*c*) Adjust the pressure in the cylinder.
   (*d*) Prevent condensation of the oxygen.

7. The color of acetylene hose of the welding outfit is—
   (*a*) Yellow.
   (*b*) White.
   (*c*) Red.
   (*d*) Green.

8. The oxyacetylene welding equipment is equipped with—
   (*a*) Left-hand threads on oxygen hose connection and right-hand threads on acetylene hose connections.
   (*b*) Left-hand threads on both oxygen and acetylene hose connections.
   (*c*) Right-hand threads on both oxygen and acetylene hose connections.
   (*d*) Right-hand threads on oxygen hose connections and left-hand threads on acetylene hose connections.

9. Before opening the oxygen cylinder valve, the regulator adjusting screw should be—
   (*a*) Released.
   (*b*) Removed.
   (*c*) Turned in all the way.
   (*d*) Tightened to finger tightness.

10. The type of torch flame produced by burning an excess of acetylene is—
   (*a*) Neutral.
   (*b*) Decarburizing.
   (*c*) Carburizing.
   (*d*) Oxidizing.

11. An oxidizing welding flame is produced by burning—
   (*a*) An excess of acetylene.
   (*b*) An excess of oxygen.
   (*c*) Equal parts of oxygen and acetylene.
   (*d*) A small amount of acetone in the mixture.

12. The method of welding in which the torch tip precedes the rod, and the flame is pointed back at the molten puddle is called—
   (*a*) Forehand.
   (*b*) Puddle.
   (*c*) Ripple.
   (*d*) Backhand.

13. A method of welding, used to minimize internal stresses and strains, in which one section of the joint is welded at a time in the opposite direction from the general direction of welding is referred to as —
   (*a*) Tack welding.
   (*b*) Backstep welding.
   (*c*) Stagger welding.
   (*d*) Backhand welding.

In the following matching questions, match the color markings in column *A* with the appropriate gases in column *B*.

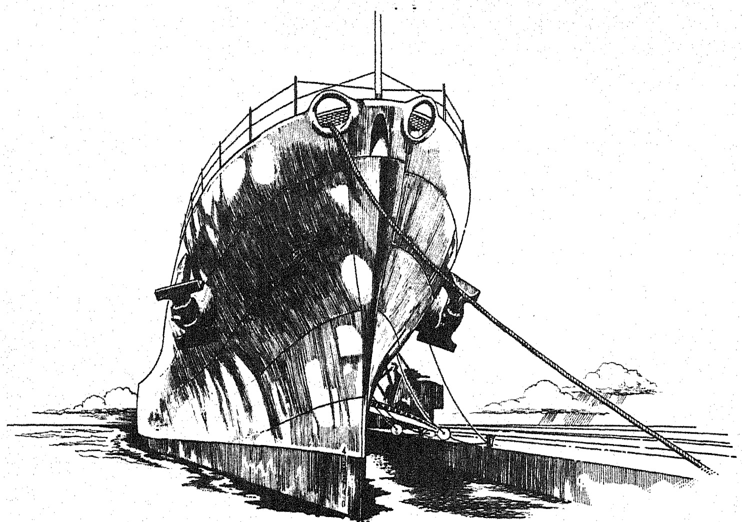
A	*B*
14. Fire extinguisher-red all over. All others—machine tool gray all over.	(*a*) Acetylene.
15. Black with 2-inch red band and white neck band.	(*b*) Air.
16. Black all over.	(*c*) Carbon dioxide.
17. Yellow with brown neck band.	(*d*) Chlorine.
18. Black all over except for 6-inch light blue neck band.	(*e*) Helium (breathing).
	(*f*) Hydrogen.
	(*g*) Nitrous oxide (technical).

In the following matching questions, match the gases in column *A* with the appropriate color markings in column *B*.

A	*B*
19. Aerosol.	(*a*) Apple green all over.
20. Ammonia.	(*b*) Black with brown neck band.
21. Ethyl oxide.	(*c*) Black with yellow neck band.
22. Nitrogen.	(*d*) Black with machine tool gray neck band.
23. Oxygen (aviator).	(*e*) Machine tool gray with orange neck band.
	(*f*) Machine tool gray with 2-inch orange band and orange neck band separated by 2-inch gray band.
	(*g*) Machine tool gray with 2-inch red band and red neck band separated by 2-inch gray band.

24–33. The following is a list of steps, briefly stated, to be followed in setting-up oxyacetylene welding apparatus. Rearrange in the proper order.

(*a*) Connect regulators to their respective cylinders.
(*b*) Attach hose to their respective regulators.
(*c*) Blow out oxygen hose; and acetylene hose if necessary, adhering to all safety precautions.
(*d*) Adjust tip.
(*e*) Light off and adjust tip flame.
(*f*) Adjust working pressures.
(*g*) "Crack" cylinder valves to blow out clean.
(*h*) Connect hose to torch.
(*i*) Release regulator screws.
(*j*) Fasten down the cylinders.



CHAPTER 9

ARC WELDING

During the first World War, the U. S. Navy used arc welding as an emergency salvage tool. The results were so successful that arc-welding gear is now recognized as standard equipment in naval shipyards, on warships, in drydocks, and marine service shops. The German pocket battleship first demonstrated the possibilities of arc welding in naval warfare. It reduced the cost of ship construction, decreased the dead weight, and increased the carrying capacity. A modern battleship now contains about a thousand miles of welds. Most of those are arc welded. Arc welding is used in the construction of bulkheads, decks, masts, piping systems, and other parts of the ship. You are going to do most of the structural arc welding aboard ship as well as the bulk of the welding required by the engineer department.

When a job comes up you'll usually be instructed by your chief as to whether the job is to be done by arc or oxyacetylene welding. But if it is left to you to decide how the job is to be

done, you'll have to use your own judgment. As a general rule, the gas—oxyacetylene—method is used for fusion welding, bronze welding, and brass brazing of sheet metals and light sections of forgings, castings, and piping. The arc is used for fusion welding of heavy plates, shapes, castings, forgings, and pipes. For many jobs the method makes little difference. When you do have to decide which method to use, consider these factors: availability of equipment, location of the welding job, and your own ability.

Arc welding is one of the major welding processes which does not require pressure to complete the weld. Arc welding is done by melting the edges of the plate, forming the joint, and flowing the edges together. Metal arc welding involves the use of electrodes for filler metal, but carbon arc may be done with or without filler metal, depending upon the type of weld. Temperatures around 6500° F. are developed in the arc between a suitable electrode and the base metal or between two electrodes. You are familiar with the spark which jumps across the gap in an automobile spark plug. It is the heat of this spark which ignites the compressed gasoline vapors. The same principle is used in arc welding—the heat of the spark or arc is used to melt the metals. In metal arc welding, the arc is maintained between a metal electrode and the base metal. In carbon arc welding, the arc is formed between two carbon electrodes or between a carbon electrode and the base metal. In atomic-hydrogen welding, the arc is formed and maintained between two tungsten electrodes.

ARC-WELDING EQUIPMENT

Electric arc-welding equipment consists of an electric arc-welding machine driven either by an electric motor or a gasoline engine, two cables, an electrode holder, metal and carbon electrodes, and equipment for personal protection.

Arc-welding machines may be classified by the type of current supplied at the arc. One type of current is direct current; the other is alternating current.

A DIRECT CURRENT WELDER is made up of a direct current

generator driven by a suitable motor or engine. The voltage produced by this generator usually ranges from 15 to 45 volts across the arc, and the current output varies from 20 to 800 amperes, depending on the type of unit. In most units the voltage output of the generator is controlled by an automatic device which adjusts the output to the demands of the arc. However, this voltage may be set by the manual adjustment of a rheostat mounted on the control panel. Amperage can also be set by hand and this is usually set to the proper range with a selector switch. If both the voltage and the amperage can be set by hand, the machine is called the dual-control type. The machine shown in figure 169 is a dual-control type of machine located on an ordnance handling truck. A ground plate is attached to the work to be welded, and the metal or carbon electrode is clamped in the electrode holder.

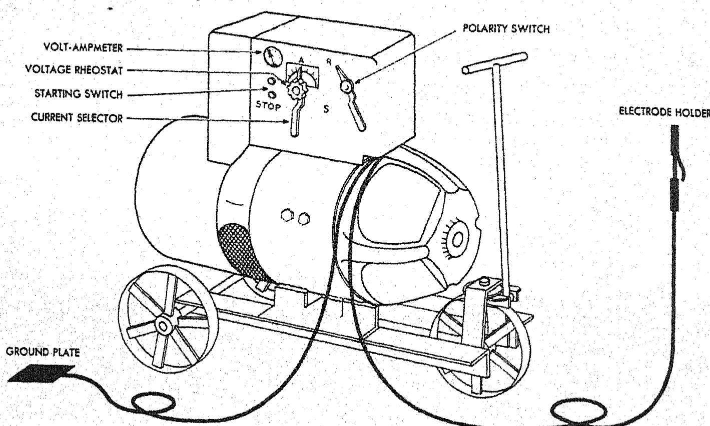


Figure 169.—Dual-control direct current, motor generator, arc-welding machine.

When a power supply is available, welding generators are usually driven by an electric motor. Some of these units are so constructed that the generator is driven by the electric motor. They are connected by means of a flexible coupling. Others are set up with the generator and the motor on the same shaft. Where a power supply is not available for your arc-welding

machine, you may have to use a motor-driven generator. In this case the motor must be equipped with a governor to compensate for the varying loads imposed by the welder.

ALTERNATING-CURRENT WELDING MACHINES are of two general types—the transformer and the motor-generator type. The transformer (cracker box) type a.c. welding machine gets its welding current from a closed core transformer. The primary coil of this transformer is hooked up directly with the power line, and the secondary coil is tapped at intervals to vary the welding current strength.

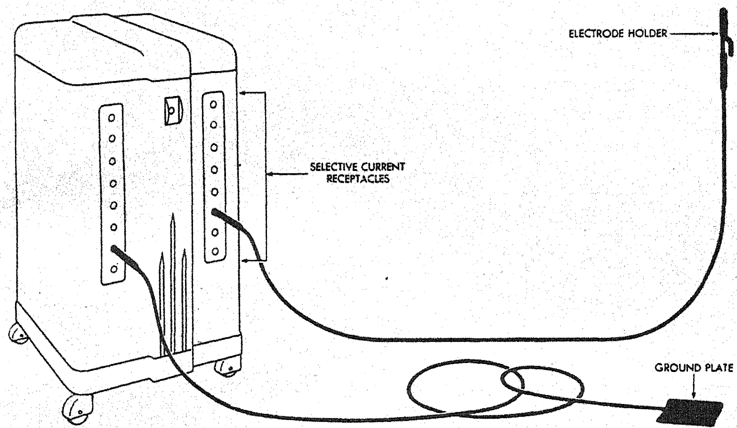


Figure 170.—Typical transformer-type alternating current arc-welding machine (cracker box).

The a.c. motor-generator type welding machine is supplied with current by a high frequency generator which has a two-position switch that allows you to change the output from a high to a low value. Except for the fact that you will have to use a heavily coated electrode with alternating-current welding machines, you'll find them about as adaptable as the direct-current machines.

On board ship you will work from a panel which is supplied with current from two master generators. On repair ships and tenders you'll have both alternating current and direct current.

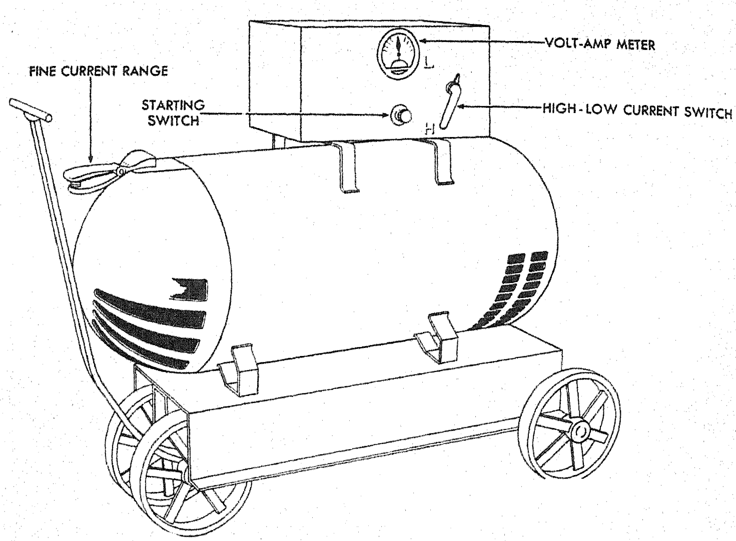


Figure 171.—Typical motor generator type alternating-current type welding machine.

You'll also have portable machines mounted on a truck or dolly.

The CABLES used with welding machines must have ample current-carrying capacity and be insulated with a heavy rubber cover. One end of the cable is attached to the work table and the other to the ground lug of the welding machine. The other cable must be more flexible, as it is attached to the electrode holder on one end and to a lug on the machine on the other end.

The electrode holder, usually referred to as a stinger, is an insulated clamping device for holding the electrode (see figure 172). The electrode may be clamped in any desirable angle, but it must make good electrical contact with the jaws. The holder must be light in weight and be capable of carrying the required current for welding without overheating.

ELECTRODES

Metal electrodes used for arc welding comes in sizes ranging from 1/16 inch to larger than 3/8 inch in diameter, and 9, 12, 14, and 18 inches in length. These sizes are available in bare,

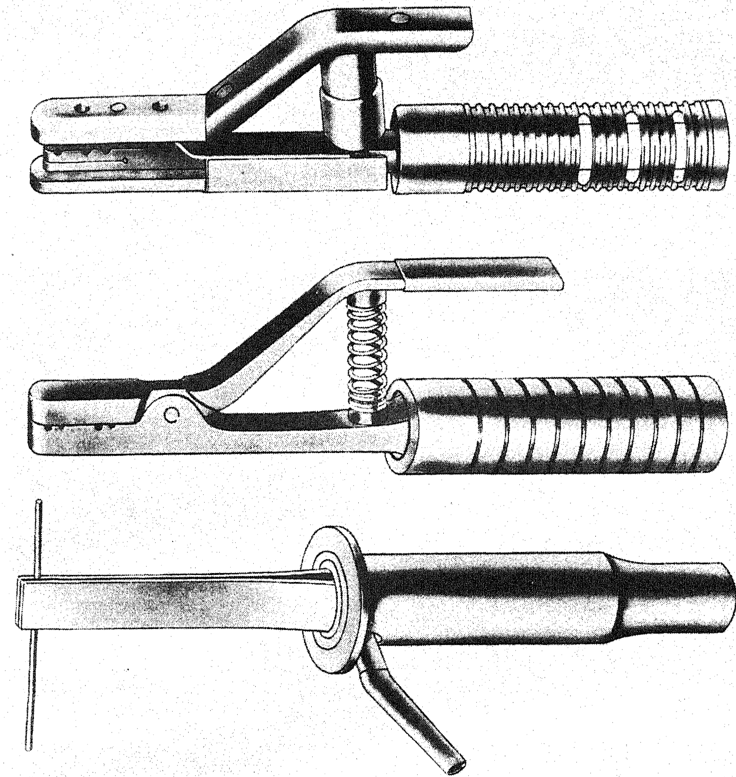


Figure 172.—Electrode holders.

light or wash-coated, and heavy-coated or shielded-arc types.

Most of your important metal arc welds are made with heavy-coated electrodes because of the greater strength and ductility of the weld metal as compared with that you get from bare electrodes.

CARBON ELECTRODES come in lengths of 12 inches and diameters ranging from $\frac{5}{32}$ to 1 inch. They are made from pure graphite or baked carbon and are used for carbon arc welding with bare or flux-coated filler rod.

BARE ELECTRODES are made of wire having a certain predetermined composition. Their surface is not treated by anything

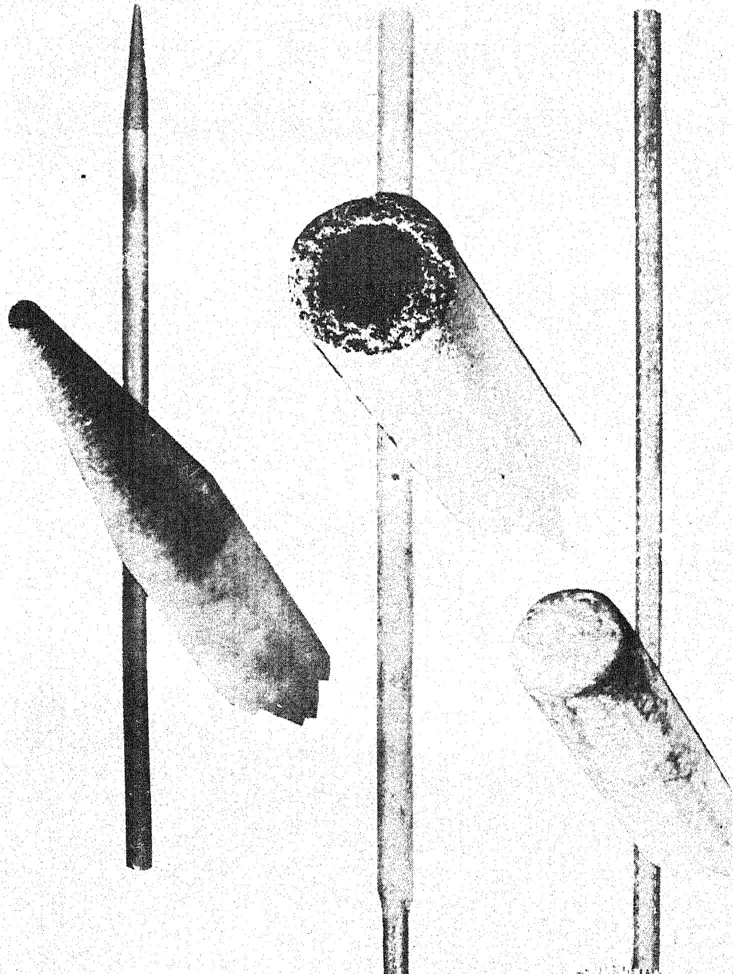


Figure 173.—Three types of arc-welding electrodes.

other than the materials left over from the wire-drawing operation. Finished annealed wire is classified as a bare electrode.

Thinly coated electrodes are made of wire of a definite composition with a thin coating of iron oxide and titanium dioxide. The coating serves to improve the stability and characteristics of the arc stream. The coatings dissolve or reduce impurities like oxide, sulphur, and phosphorus and keep them out of the weld deposit. The coatings also make the flow of molten metal more uniform and continuous. Some of these coatings may produce a slag, but it is thin. Figure 174 illustrates the action of light-coated electrodes in welding.

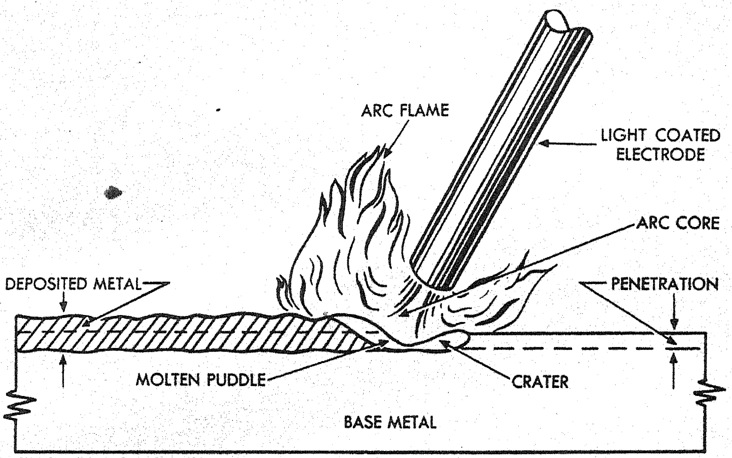


Figure 174.—Action of light-coated electrode.

Shielded-arc or heavy-coated electrodes are made of wire of definite composition and are heavily coated. The coatings are designed to improve the physical properties of the weld deposit and control arc stability. As a result they increase the speed of welding and the ease of welding in the overhead and vertical positions. The protection provided by the heavy coating keeps oxygen from the air from combining with the molten metal of the weld deposit to cause porosity and oxidizing or burning of the weld. Without the protection of the heavy coating, nitrides would also be found in the welds in hard particles which would cause brittleness, low ductility, low strength, and poor resis-

tance to corrosion. The heavy coatings, then, protect the weld deposit by both chemical and mechanical action.

There are two general types of coatings for electrodes: cellulose coatings and mineral coatings. Combinations of both types are also used. The cellulose-coated shielded types are made from wood pulp, sawdust, cotton, or compositions secured from rayon. The mineral-coated shielded types are derived from asbestos and clay. Other materials used for electrode coatings are burnt sugar, gums, and starches. The first type, cellulose, depends upon a gaseous shielding or covering around the arc stream as well as upon a slag covering over the weld metal. The mineral type depends upon the slag as a shield.

The action of the shielded-arc or heavy-coated electrode is illustrated in figure 175.

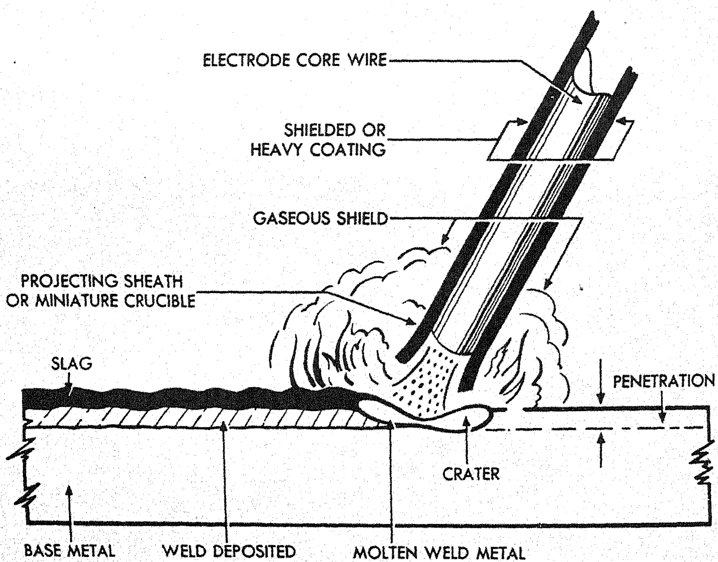


Figure 175.—Arc characteristics of heavy-coated electrodes.

To do a good job of arc welding you must have certain accessories in addition to your welding equipment.

A COMBINATION CHIPPING HAMMER AND WIRE BRUSH is required to loosen the slag and clean each weld bead before further welding. The wire brush is replaceable on a tool of this kind.

A WELDING TABLE is a must in a well-equipped shop. If your ship isn't equipped with a welding table, you can make one like the table illustrated in figure 176. It should be constructed of steel with legs of pipe or angle iron. The top should be made of

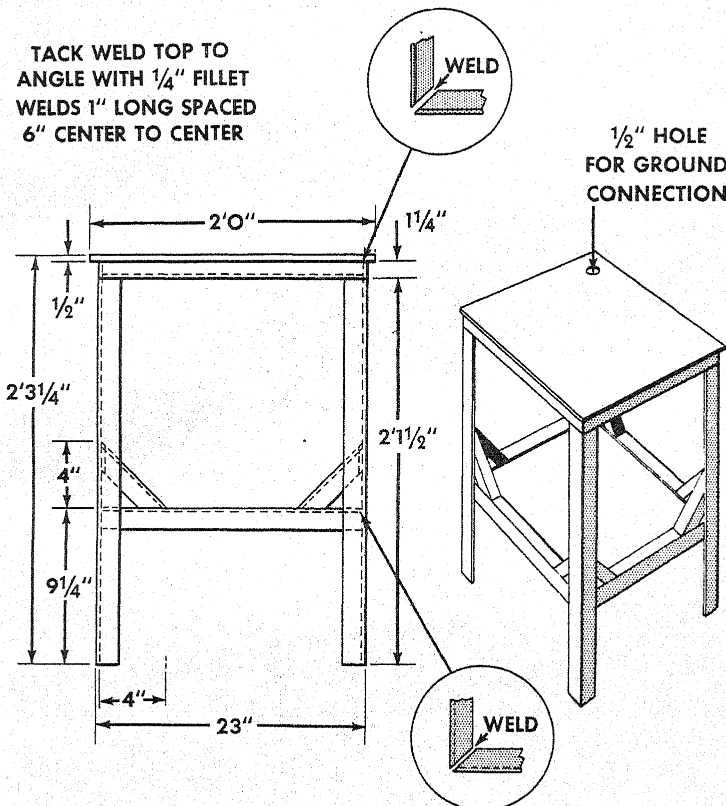


Figure 176.—Build your own welding table.

a steel plate. A container for electrodes and an insulated hook for the electrode holder should be provided.

You'll also need some common C-clamps or other clamp brackets to hold your work in position for welding. It's a good idea also to collect some strips and bars of copper and cast iron to use for back-up bars when you are welding light sheet. You'll probably also need some carbon blocks, asbestos, or fire clay to use in making molds when building up sections.

ON GUARD

For your own personal protection you'll need helmets or face shields, gloves, and protective clothing. You should never expose your eyes or skin even for an instant to the ultra-violet and infrared rays of the electric arc. If you do, it will result in what welders call "hot sand in the eyes." This doesn't result in permanent injury but it is painful while it lasts. The effect on the skin is similar to sunburn. You must also consider the people working around you. Shields should be provided for their protection. Your hands should be protected from burns from hot metal as well as from the rays. Gloves, sleeves, and aprons of chrome leather or spark-resisting duck like the ones shown in figure 177 should be worn.

If your welding involves zinc you will notice an irritation in the nose and throat after breathing heavy concentrations of the fumes. This is caused by zinc fumes which attack the membranes. The best preventive measure is to have the compartment well-ventilated.

ARC-WELDING PROCEDURE

The welding machine controls for amperage, voltage, and other adjustments must be set to provide the correct current for the following: the electrode used, the thickness of the plate being welded, the position of the weld, and the welder's skill. No specific directions are given here for setting the controls because they vary on the different types and sizes of machines

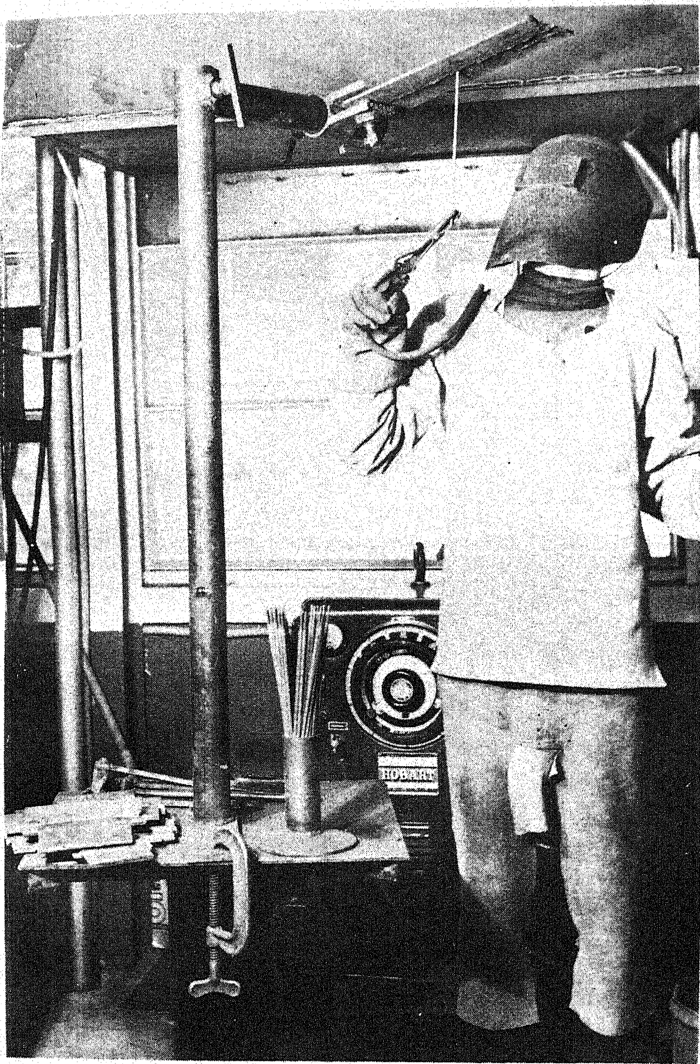


Figure 177.—Metalsmith properly clothed for arc-welding.

made by different manufacturers. Get an experienced welder to break you in on the machine you'll use. As you gain experience, you'll learn to make your own adjustments, using data published by the manufacturers only as a guide. Experience is the best guide for making the necessary adjustments to fulfill the requirements of the job. For the first setting of the machine the first table in figure 178 may be used when welding with bare and lightly coated electrodes. The arc voltage will vary from about 17 volts for 3/32 inch electrodes to 30 volts for 3/8 inch electrodes of either the bare or lightly coated types. You generally won't use an electrode of more than 3/16 inch diameter for overhead or vertical welding positions.

RANGE OF CURRENT SETTINGS FOR BARE AND LIGHTLY COATED ELECTRODES

Electrode Diameter	Amperes Minimum		Amperes Maximum	Standard Electrode Lengths
1/16 in.	40	-	60	—
3/32 in.	70	-	90	11½ in.
1/8 in.	110	-	135	14 or 18 in.
5/32 in.	150	-	180	14 or 18 in.
3/16 in.	180	-	220	14 or 18 in.
1/4* in.	250	-	300	14 or 18 in.
5/16* in.	300	-	425	14 or 18 in.
3/8* in.	450	-	550	14 or 18 in.

* Diameters, 1/4-in., 5/16-in., and 3/8-in., are for flat position only.

COMPARISON OF CURRENTS USED WITH GASEOUS AND SLAG TYPES OF ELECTRODE

GASEOUS TYPE			SLAG TYPE	
Electrode Diameter	Flat Position (Amperes)	Vertical and Overhead Positions (Amperes)	Electrode Diameter	Flat Position (Amperes)
3/32 in.	60	60	1-	—
1/8 in.	120	110	1/8 in.	130
5/32 in.	150	140	5/32 in.	160
3/16 in.	175	160	3/16 in.	200
1/4 in.	250	-	1/4 in.	300
5/16 in.	325	-	5/16 in.	400
3/8 in.	425	-	3/8 in.	500

Figure 178.— Range of current settings.

The mineral-coated type of shielded-arc electrode, which produces a slag as a shield, requires higher welding currents than the cellulose-coated type, which produces large volumes of gases to shield the arc stream. The second table in figure 178 shows a comparison of the current required for the mineral-coated or slag-forming electrode and the cellulose-coated or gaseous type of electrode. The voltage will vary from about 20 volts for the $\frac{3}{32}$-inch electrodes to 30 volts for the $\frac{3}{8}$-inch heavy-coated electrodes of either type.

In addition to proper adjustment for current and voltage to give proper welding conditions for the particular size and type of electrode used, it is necessary to consider POLARITY.

The POLARITY of a direct current welding arc may be straight or reversed. In straight polarity the electrode is always negative. In reverse polarity the electrode is positive (see figure 179). The polarity recommended for use with a particular type electrode is specified by the manufacturer. Generally, straight polarity is used for all mild steel, bare or lightly coated electrodes. In welding nonferrous metals such as aluminum, bronze, monel. nickel, and also with some heavy-coated electrodes, reverse polarity is used. Reverse polarity is also used for making vertical and overhead welds. The proper polarity can be recognized by the sharp cracking sound of the arc. Improper polarity for a given electrode will cause the arc to give off a hissing sound and will make control of the welding bead difficult.

After the machine has been properly adjusted, the bare end of the electrode should be gripped in the electrode holder so that the entire length of the electrode can be deposited without breaking the arc. If you are welding with a very long electrode, you may find it worth while to bare the center of the electrode for the holder grip. Carbon or graphite electrodes should be gripped short of the full length to avoid overheating the entire electrode.

STRIKING THE ARC

There are two ways of getting the arc started after you have properly set up and adjusted your welding machine. These are

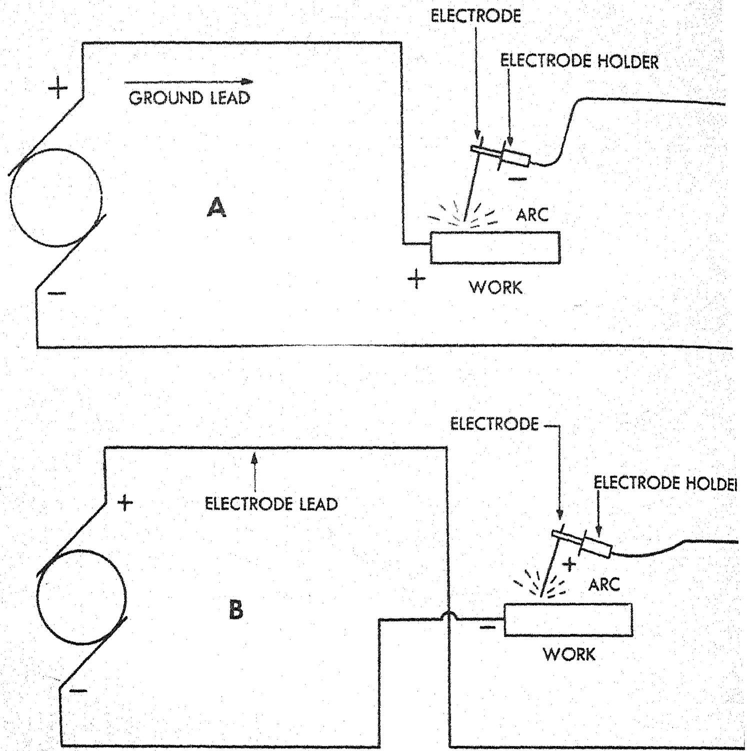


Figure 179.— Polarity in arc welding.

the striking or brushing method, and the tapping method. In either method the arc is formed by short-circuiting the welding current between the electrode and the joint to be welded. The heat of the high current at the arc causes both the end of the electrode and the spot struck on the metal to melt instantly.

IN THE STRIKING OR BRUSHING METHOD, the end of the electrode is brought down to the work in a continuous motion that describes the arc of a circle. As soon as you touch the surface of the base metal, the downward motion is checked and the electrode is raised to make the arc. The distance between the

electrode and the base metal should be about equal to the diameter of the electrode. You'll know by the sharp crackling sound when you have the right length arc.

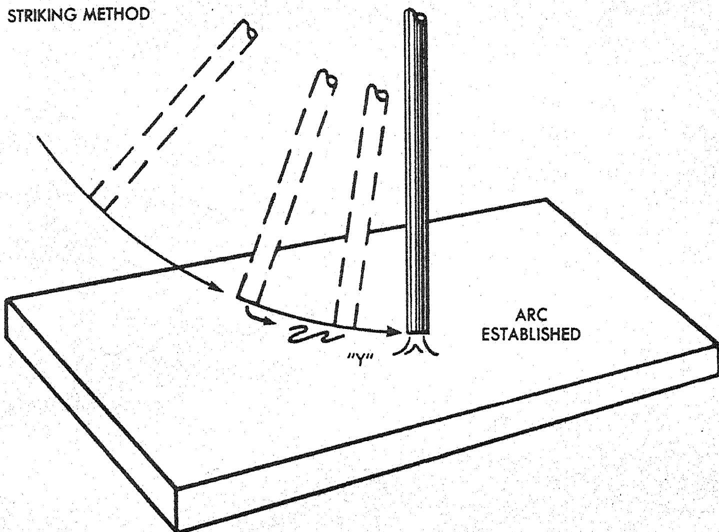


Figure 180.— Striking or brushing method of starting the arc.

IN THE TAPPING METHOD, you hold the electrode in a vertical position to the plate. You establish the arc by lowering the electrode and tapping or bouncing it on the surface of the base metal and then slowly raising it a short distance.

When you strike the arc, be sure not to raise the electrode too quickly or the arc length will be increased too much and you will lose the arc. If you raise it too slowly, the electrode will freeze or stick to the base metal. When this happens, you can usually free it by a quick sidewise wrist motion. If the electrode is not freed by this motion, remove the holder from the electrode or stop the machine. A light chisel blow will then free the electrode and it can again be gripped in the holder. Don't remove your helmet or shield from your eyes while working with the electrode.

After the arc is struck, particles of metal melt off the end of the electrode, and are fed into the molten crater of the base metal. This causes the electrode to shorten and the arc to increase in length unless you keep moving the electrode closer to

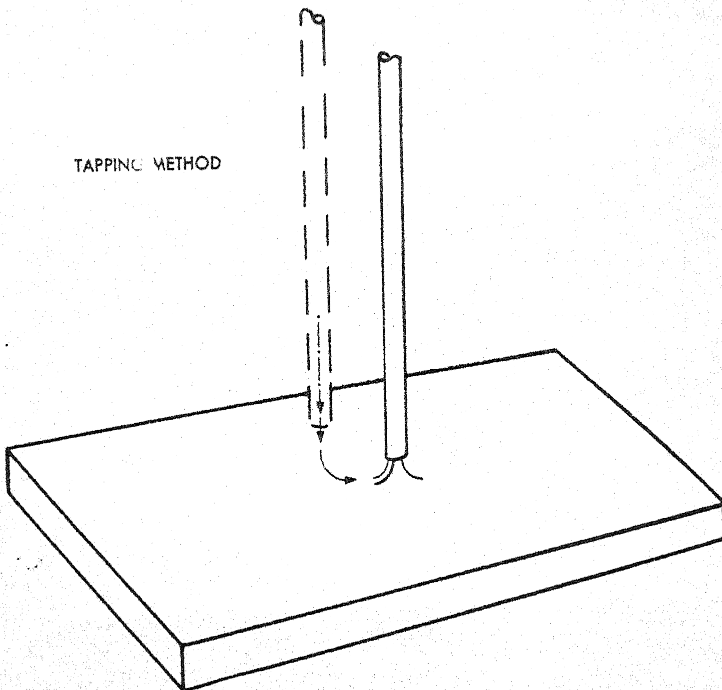


Figure 181.—Tapping method of starting the arc.

the base metal as the end is fed off. If the electrode is fed down to the plate and along the surface at a constant rate, a bead of metal will be deposited or welded on to the surface of the base metal. Before you advance your arc, hold it for a short time at the starting point to insure good fusion and to build up the bead slightly. Good arc welding depends upon good control of the motion of the electrode down to and along the surface of the base metal.

In general, the types of welds and types of joints for arc welding are the same as those used in gas welding. Also the positions of welds are the same as in gas welding, and like gas welding, arc-welding technique must differ somewhat for the different positions used. The position of the electrode in relation to the joint being welded is a factor of prime importance.

For welding a BEAD in the FLAT POSITION, the electrode should be held at a 90° angle to the base metal. In order to get a good view of the molten puddle, you may find it convenient to tilt the electrode from 5° to 15° in the direction of welding. Don't move the electrode from side to side, but move it forward just fast enough to deposit the weld metal uniformly, and move it downward as rapidly as the molten metal is deposited to keep the arc constant.

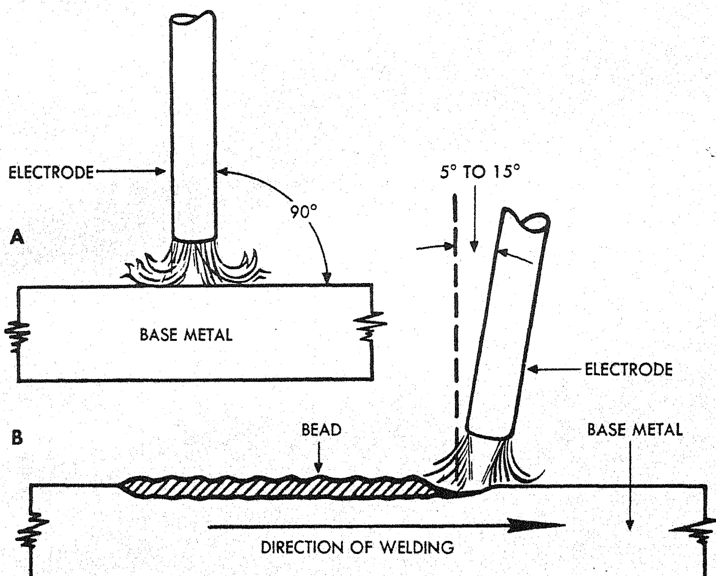


Figure 182.—Position of electrode in making a bead in the flat position.

Hold a short arc and weld in a straight line at a constant speed. You can't judge the proper length of arc by looking at it, so you will have to depend upon recognizing the sound made by a short arc. This is a sharp cracking sound and it should be heard all during the time the arc is being moved along the surface of the plate.

A good bead weld should have the following characteristics:

1. Little or no splatter on the surface of the plate.
2. An arc crater in the bead of approximately $\frac{1}{16}$ inch when the arc has been broken.
3. The bead should be built up slightly but have no metal overlap at the top surface.
4. A good penetration of approximately $\frac{1}{16}$ inch into the base metal.

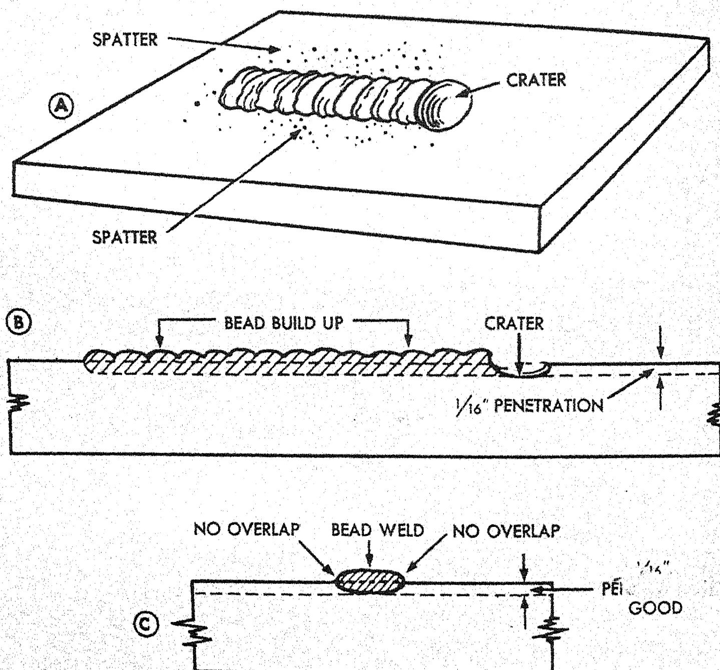


Figure 183.— Properly made bead welds in the flat position.

A BUTT joint in the FLAT POSITION is set up in the same manner as for gas welding. Plates from 1/8 to 1/4 inch can be welded in one pass. No edge preparation is necessary for this type of weld, but the pieces of the base metal should be tacked together to keep them aligned. The electrode motion is the same as for forming a bead in the flat position. When you are welding plate 1/4 inch or more in thickness, the edges of the plate should be prepared by beveling or U-grooving, and any of the joints illustrated earlier in this book may be used, depending upon the thickness of the metal to be welded. The first bead is deposited to seal the space between the two pieces of the joint and to weld the root of the joint. This bead must be thoroughly cleaned to remove all slag before the second pass is made. The second,

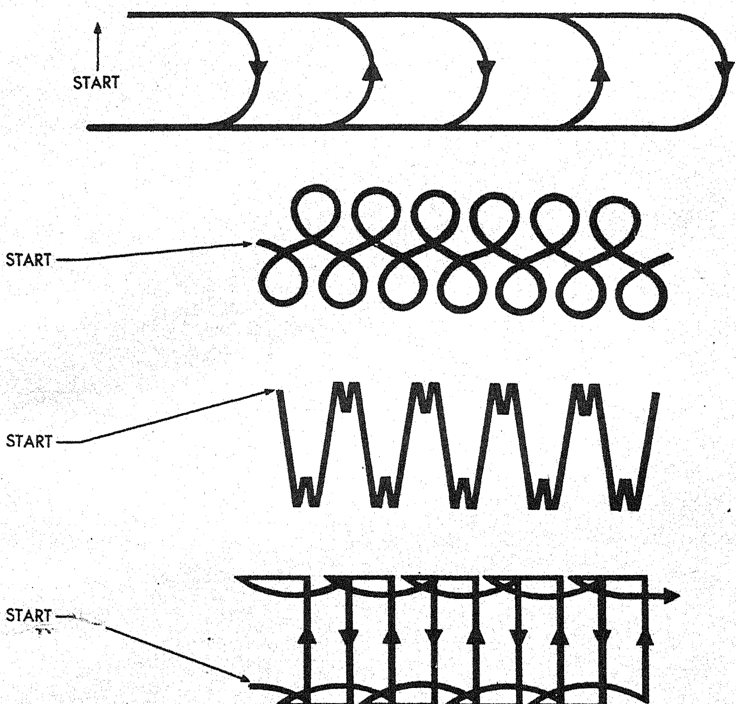


Figure 184.— Weave motions.

third, and fourth layers of weld metal are deposited in a weaving motion. Any of the methods shown in figure 184 may be used, depending upon the type and size of the electrode.

You'll have to clean each layer of weld metal before another is deposited, and you'll have to be careful not to undercut. To prevent undercutting, pause at the end of each turn of the weave on the edges of the joint.

If you find that you are having trouble getting good penetration at the root of butt welds in the flat position, you may use a back-up strip. The back-up strip should be about an inch wide and 3/16-inch thick. Tack-weld the strip to the base of the joint and use it for a cushion for the first layer of weld metal deposited in the joint. Then complete the joint by adding additional layers of weld metal in the same way that you would for an ordinary butt joint. When the weld is completed, you can wash off or cut away the strip with your cutting torch and add a seal bead at the back if it is needed.

FILLET welds are used to make T-, and lap joints in the FLAT POSITION.

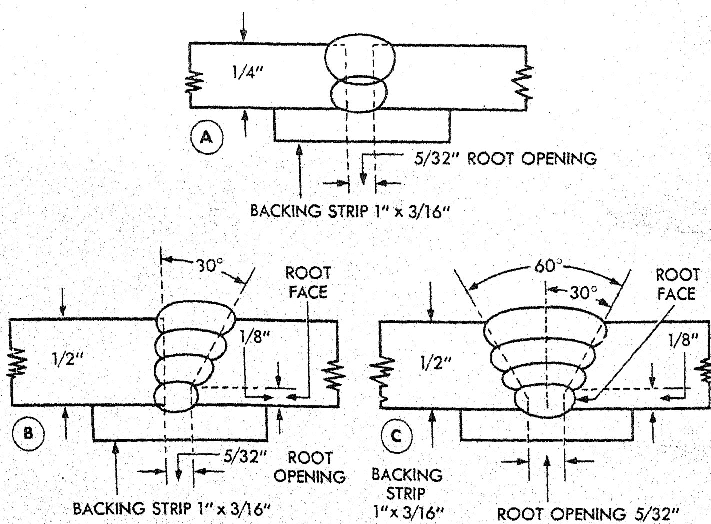


Figure 185.— Butt welds with backing strips.

When you set up a **T**-joint in the flat position, you'll form an angle of 90° between the surfaces of the two pieces of plate being welded. First, tack-weld them in position by welding a tack at the ends. Use a short arc, and hold the electrode at an angle of 45° to the plate surfaces. Tilt your electrode about 15° in the direction of welding. Light plates can be welded without using a weaving motion of the electrode, and they can be welded in one pass. Heavier plates may take two or more passes, and if they do, a semicircular weaving motion is used with the second pass to get good fusion without undercutting.

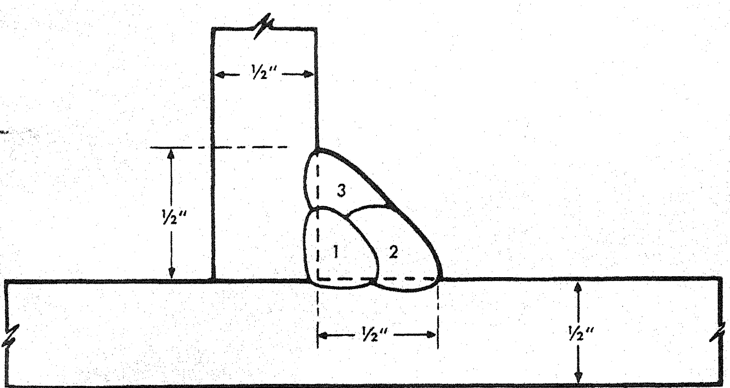


Figure 186.—Fillet weld on T-joint in horizontal position.

If you are using ½-inch plate or heavier, use string beads in the order shown in figure 187.

Lap joints are made in the same way as **T**-joints except that the electrode should be held so as to form a 30° angle with the vertical. This angle is more nearly straight up than that used for the **T**-joint.

Plug and slot welds are used to weld overlapping plates together by welding through a hole or slot in the upper plate to the surface of the lower plate.

Slot welds are used to join face-hardened plate from the back or soft side. You can also use slot welds to fill up holes in plate

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or to join two overlapping plates where you can't join them by some other method.

Plug welds may also be used to remove bolts or studs that have broken or twisted off flush with the surface of a casting. Just place a nut over the stud and weld it to the stud with a

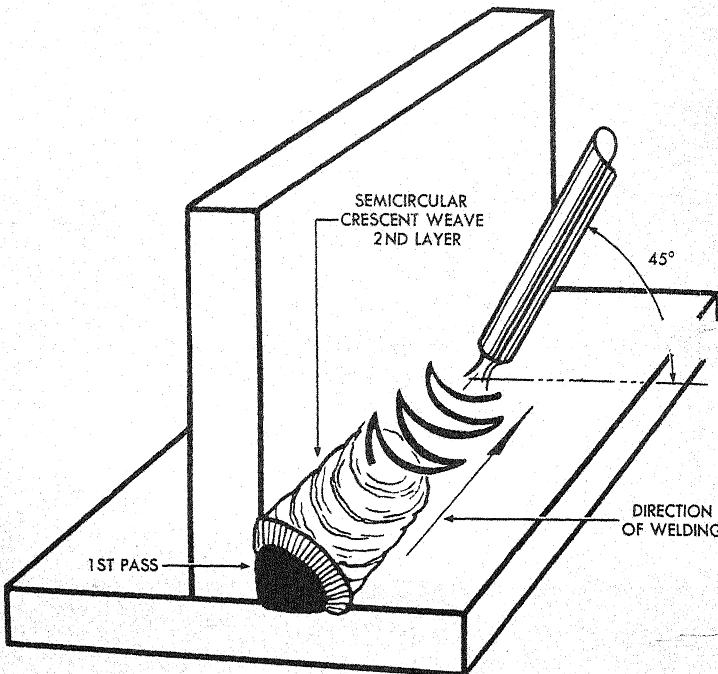

Figure 187.—String bead welds on heavy plate T-joints in the horizontal position.

heavy-coated steel electrode. This will weld the nut to the stud so that you can use a wrench on the nut to turn the stud and remove it.

The OVERHEAD POSITION is the most difficult of the welding positions. The following pointers will help you to get a good overhead weld if you will observe them carefully:

1. Keep a very short arc. This will help you to retain complete control of the molten puddle.

2. Hold the arc at 90° to the base metal when welding a bead.
3. Avoid excessive weaving in the overhead position as this will cause overheating of the weld metal and form a large pool which is hard to control.

Butt JOINTS in the OVERHEAD POSITION are best made with back-up strips. String beads are better than weave beads for this type of weld, but each bead must be cleaned and the rough areas should be chipped out before the next pass is made. Figure 188 illustrates the proper position of the electrode in relation to the joint and the proper sequence for running beads.

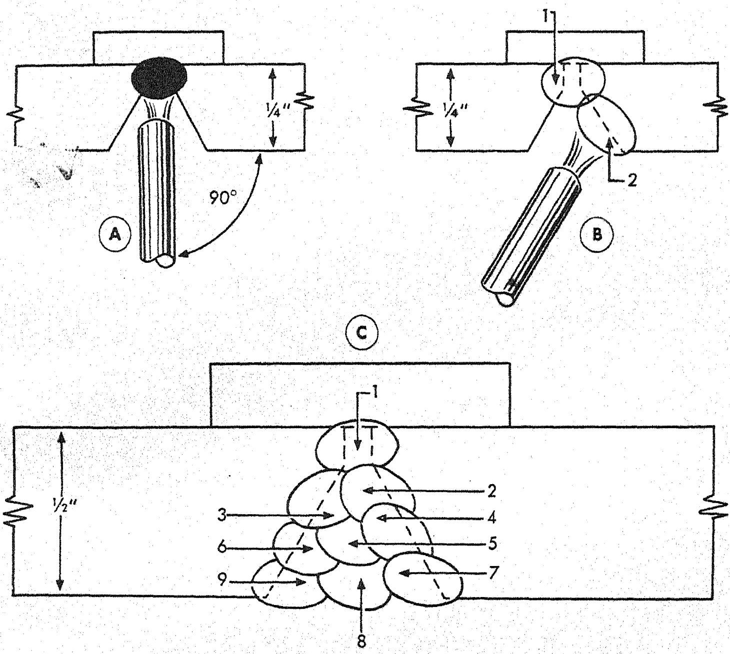

Figure 188.— Welding butt joint in the overhead position.

FILLET WELDS in the OVERHEAD POSITION are used in making either **T**- or lap joints. Here also a short arc is held and no weaving is required. Hold the electrode about 30° from the vertical plate and move it uniformly in the direction of welding.

Control the arc motion to get good root penetration and good fusion with the sidewalls. If you get too big a pool of molten metal and it begins to sag, whip your electrode away from the crater ahead of the weld, lengthening the arc and allowing the metal to solidify. Then return the electrode immediately to the crater of the weld and continue the welding. Heavy plate may require several passes to make either T- or lap joints in the overhead position. The second, third, and fourth passes are made with a slight circular movement of the end of the electrode while the top of the electrode is tilted about 15° in the direction of welding. Each bead must be cleaned thoroughly of all slag and oxides before the succeeding bead is added. Chipping and wire brushing is the best method for cleaning.

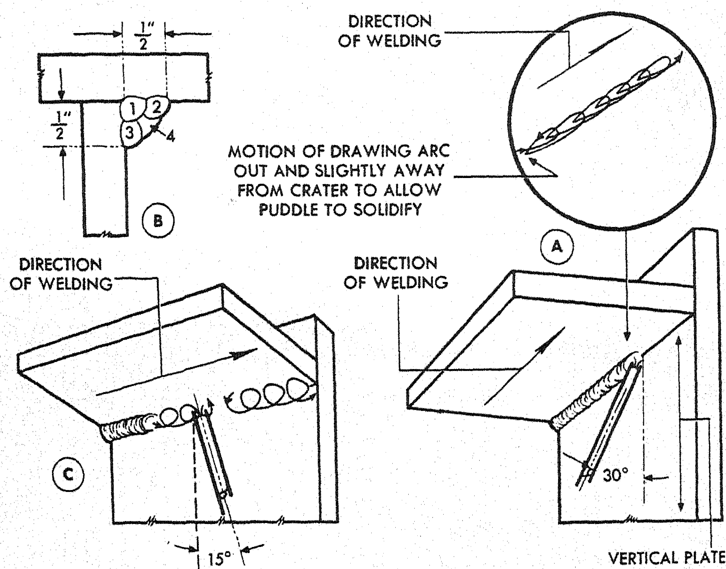

Figure 189.—Fillet welding in the overhead position.

Welding in the VERTICAL POSITION is more difficult than welding in the flat position because the force of gravity gives the molten metal a tendency to run down. Here again a short arc and careful control of the voltage are important. Current

settings or amperage is less for welding in the vertical position than for welding in the flat position. Less current is used for welding down than for welding up in the vertical position. When welding up hold the electrode at 90° to the vertical, and when welding down hold the electrode about 15° from the vertical in the direction of welding (see figure 190).

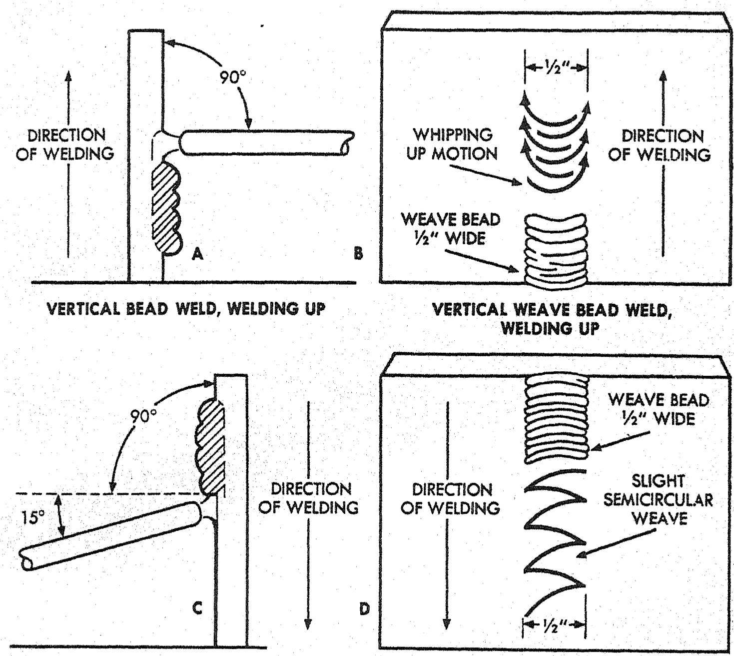

Figure 190.— Welding in the vertical position.

BUTT JOINTS welded in the vertical position are best made with a triangular motion (see figure 191). If, however, these joints are of ½-inch or heavier plate you may find that several passes will be required to get a good joint.

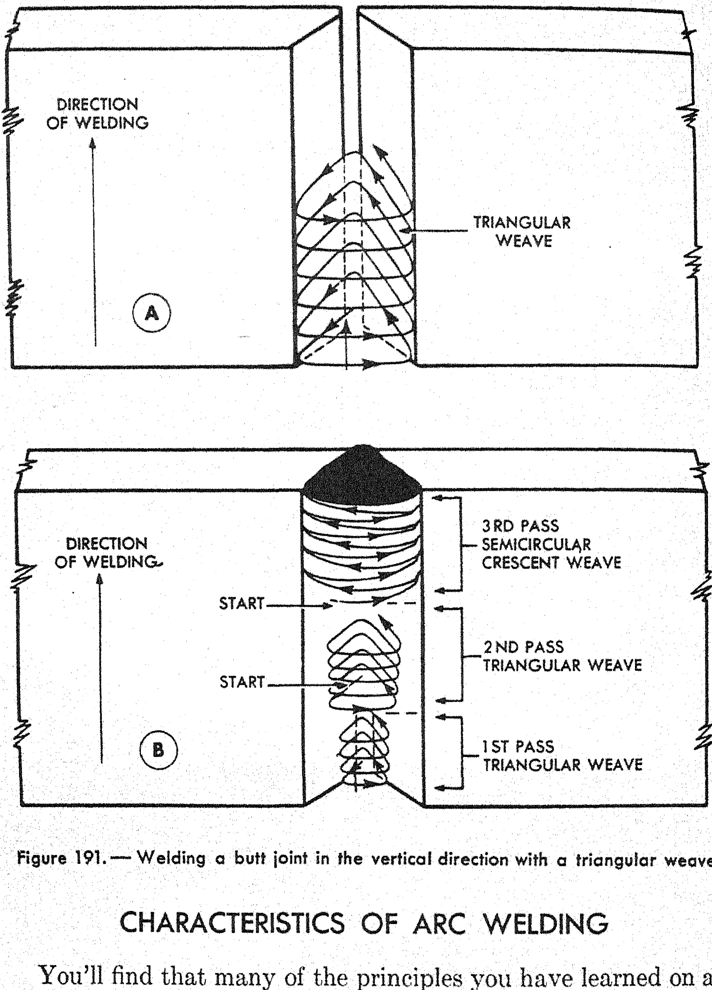

Figure 191. — Welding a butt joint in the vertical direction with a triangular weave.

CHARACTERISTICS OF ARC WELDING

You'll find that many of the principles you have learned on a previous job will be adaptable to the job at hand. Remember, too, the things you have tried that failed to work. For most of them there is a sound reason Keep your eyes peeled every time you have a chance to see an experienced welder at work and then put into practice at your very first opportunity the things that you have learned. There is nothing you can substitute for experience.

The transfer of metal from the electrode to the base metal is one of the mysteries of arc welding. You'll no doubt begin to wonder just what causes this transfer before you have run many passes. As yet scientists have been unable actually to put their finger on the one thing that causes it, but it is known that there are five forces that account for the transfer; namely, gravity, gas expansion, electromagnetic forces, electric forces, and surface tension.

The first of these, GRAVITY, is the main force that accounts for the transfer of metal in flat-position welding. You'll find that in the other positions it'll be wise to use smaller electrodes so that you won't have so large a pool and thereby lose excessive molten metal and slag by the pull of gravity.

Gases are formed by the burning of the electrode coating and they are expanded by the heat of the boiling electrode tip. This GAS EXPANSION pushes the molten metal away from the solid electrode tip in globular form and into the molten crater or weld. The coating extending beyond the tip of the electrode controls the direction of the expansion and directs the molten metal into the weld.

The tip of the electrode is a conductor of electricity. The molten globules formed at the end of the tip also are conductors. As conductors, the molten globules are affected by the magnetic force acting upon them at right angles to the flow of the electricity. These ELECTROMAGNETIC FORCES produce a pinching effect on the globules and speed up their separation from the end of the electrode. This force is particularly helpful in transferring metal from the electrode to the base metal in the vertical and horizontal position.

The ELECTRIC FORCES produced by the voltage across the arc help to pull the molten globules from the electrode to the base metal. This force is especially helpful when direct-current, straight-polarity, mineral-coated electrodes are used. Remember that mineral-coated electrodes do not produce much gas.

If a needle is greased and gently placed on the surface of water, it will float. The surface of the water behaves as if it

were covered with a thin elastic film. This is SURFACE TENSION. It is this same force that keeps the molten metal and slag in contact with the molten puddle of the base metal. This is the force that keeps the molten metal in position in horizontal, vertical, and overhead welds.

Other characteristics of the electric arc that you will encounter

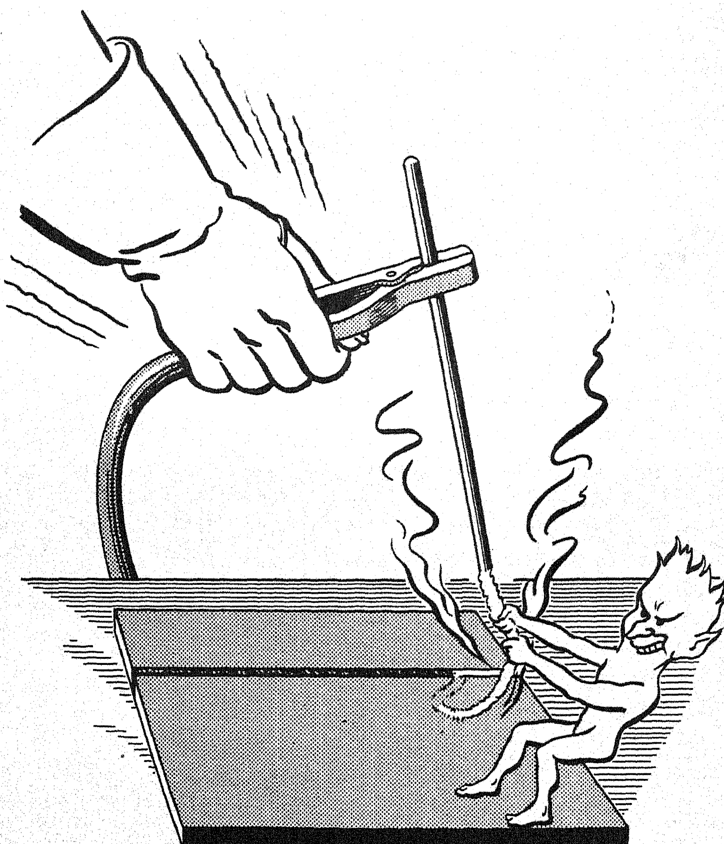

Figure 192.—Arc blow.

are ARC CRATER and ARC BLOW. An arc crater is formed by quick withdrawal of the electrode. This leaves a hole or crater in the base metal that can be used as an indication of the depth of penetration or fusion that you are getting in your weld. These craters are formed by the pressure of the gases from the electrode tip forcing the weld metal toward the edges of the crater. They may be filled at the end of the bead by withdrawing the electrode slowly. If the crater is not filled, it is likely to cause the weld to crack when it cools.

An understanding of some of these principles may help you overcome some of the difficulties that you will encounter as an inexperienced welder.

ARC BLOW is one of the more frequent annoyances that the inexperienced welder has to contend with. When welding an I-beam, a U-beam, or when approaching any abrupt turn in welding, an arc magnetism develops about the path of the welding current, making the arc unstable and difficult to control. The experienced welder will recognize this tendency before he loses control, and he will take corrective measures. Unless you learn to recognize the signs, you'll find yourself often unpleasantly surprised, and the proud owner of a bad welding job. Your first warning will come when the magnetic forces take control of your arc and cause it to weave around like a boot on his first shore leave. If you don't do something then and quick, the heat becomes so intense and the changes so rapid that you'll lose your arc with an explosive burst that will carry away the molten metal from the weld.

There are several ways of controlling or preventing arc blow. Some of these are: moving the ground to another location, wrapping one of the leads about the object to be welded, working toward the ground from any bend in the weld line, or tilting the electrode.

Experience will teach you to recognize the signs before the blow occurs, just as experience will be your guide for a lot of other procedures in arc welding. Study carefully the following table and apply this information along with your knowledge of welding know-how and you'll soon be turning out an A-1 job.

BASE METAL OR ALLOY	WELDING ELECTRODE MATERIAL	PREHEATING REQUIRED
Wrought iron	Mild steel	None.
Low-carbon iron	Mild steel	N
Low-carbon steel	Mild steel	
Medium-carbon steel	Mild steel or high strength	ou will encounter
High-carbon steel	Mild steel or high strength	
Tool steel	Mild steel or high strength	L
Plain carbon cast steel	Mild steel	200
High manganese cast steel	25/20 stainless and nickel manganese	None.
Gray cast iron	Monel or mild steel	700° to 800° F.
Low-alloy high-tensile steels	Same as base metal	Varies from 200° to 1000° F.
Stainless steels	25/20 or columbium bearing 18/8 stainless steel	None.
Deoxidized copper	Same as base metal	500° to 800° F.
Commercial bronze and low brass	Phosphor bronze, silicon copper	200° to 300° F.
Aluminum alloys	95% aluminum—5% silicon electrode	500°
Nickel	Nickel	20C
Monel	Monel	200
Inconel	Same as base metal	200° t

NOTE.—Reverse POLARITY should be used in arc welding all of the base metals or alloys except LOW-CARBON STEEL. USE STRAIGHT POLARITY FOR LOW-CARBON STEEL, and use a bare or light-coated type electrode. For the other metals mentioned, a shielded arc type electrode should be used.

CARBON ARC WELDING

Carbon arc welding is a process in which a carbon electrode or electrodes are used with or without filler You won't use carbon arc much in the welding of steels. You will, however, find that you can use the carbon arc with success in the welding of aluminum and aluminum alloys, copper and copper alloys, monel and nickel sheets. You can satisfactorily weld low-carbon sheet and plate up to ¾ inch in thickness with the carbon arc process. You can weld the thinner sections without a filler metal, but on heavier sections you'll use a filler metal usually of the same material as the base metal.

Set the polarity switch on straight polarity (electrode negative) for carbon arc welding. For joints in sections up to about 3⁄16 inch you'll use about 100 amperes and an arc length of

5/16 inch. Strike the arc against the plate edges which have been prepared in a manner similar to that used for metal arc welding. You'll use a special flux on the joint and you'll add filler metal in a manner similar to that for oxyacetylene

These cla... ...x-coated rod should be used to give you a pro-
electrode tip for...
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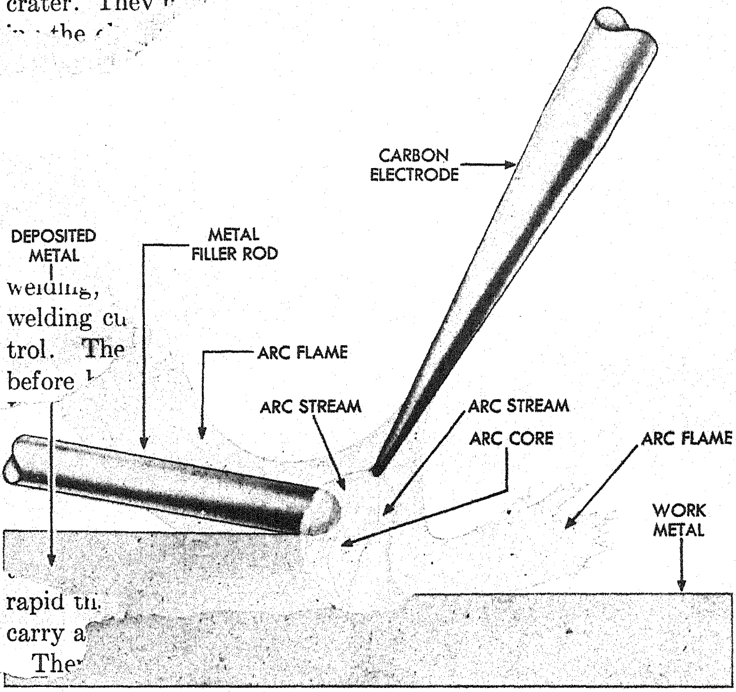


Figure 193.—Carbon arc welding.

tective atmosphere for the weld. Welding must be done without overheating or the weld metal will absorb a lot of carbon from the electrode and it will absorb oxygen and nitrogen from the air and you'll come up with a brittle joint.

The carbon electrode should be tapered to a point and held in the electrode holder a couple of inches from this point. Hold the carbon arc in about the same position in relation to the base metal as that described for the metal arc; that is,

perpendicular to the weld being made. You won't need to use a weaving motion, but you'll have to watch your rate of travel with the arc. This rate of travel or speed of welding can be only as fast as a uniform bead with a slight melting of the edges can be maintained. The amount of fusion depends upon the quantity of current used and the rate of travel of the arc. Slow welding speed increases the penetration and forms a wider heated area along the line of the weld.

GUIDE FOR CARBON ARC WELDING

BASE METAL OR ALLOY	WELDING ROD		PREHEATI[NG] REQUIR[ED]
	MATERIAL	TYPE	
Wrought iron	Mild steel	Use a flux .	None.
Low-carbon steel	Mild steel	Use a flux .	Up to 30[0° F.]
Chrome-molybdenum alloy steels	Same as base metal	Use a flux .	300° ... s...
Deoxidized copper ...	Deoxidized copper, phosphor-bronze, or silicon-copper ..	Shielded arc	500° to
Commercial bronze and low brass	Phosphor-bronze, silicon-copper ..	Use a flux .	200° t...
Spring, Admiralty, and yellow brass.......	Phosphor-bronze ..	Use a flux .	200° ...
Aluminum alloys	95% aluminum, 5% silicon electrode	Flux-coated	500° ...
Nickel..............	Nickel	Lightly flux-coated	200° to ...
Monel	Monel	Lightly flux-coated	200° to 300° F.

NOTE.—Carbon arc welding of the above metals requires straight polarity.

ATOMIC HYDROGEN ARC WELDING

The atomic hydrogen welding process uses two tungsten electrodes (see figure 195) between which an alternating cu[r]rent is maintained. At the same time a stream of hyd[r]ogen gas is blown through the arc and around the electrod... [i]nner sections of the arc breaks up the molecules of hydrogen into atoms ... filler recombine outside the arc to form molecular hydrogen again. As the atomic hydrogen recombines, it forms an intense heat which is used to fuse the metals in the same way that you use torch welding. The hydrogen around the weld area keeps ...

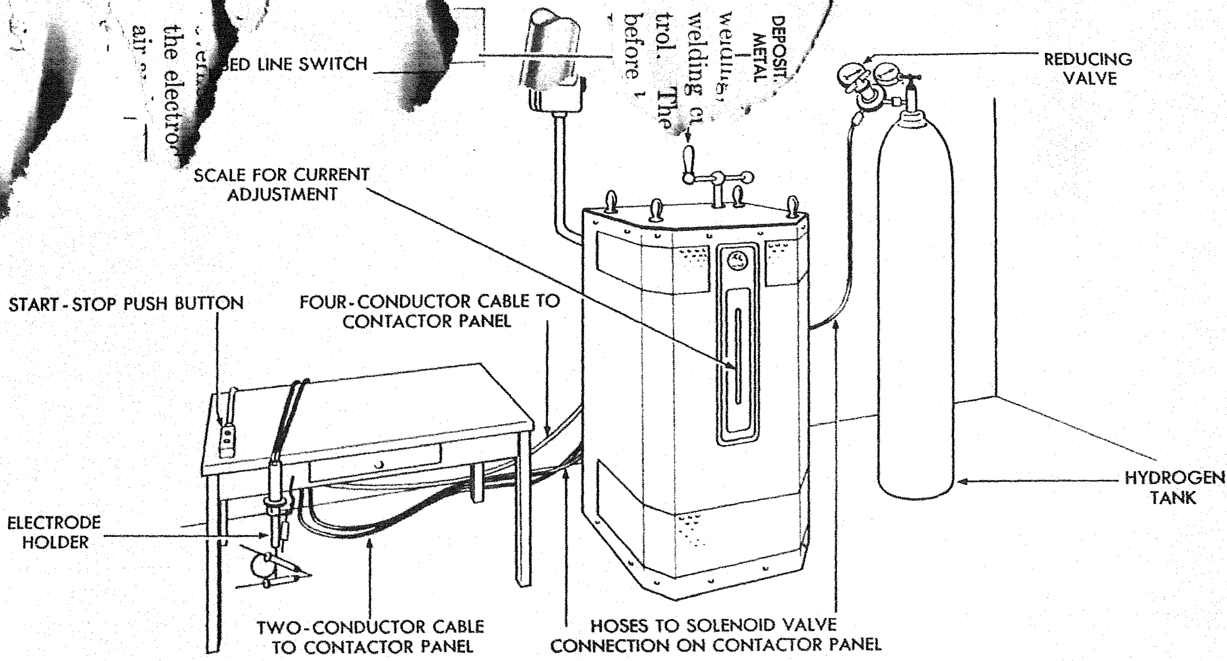


Figure 194.—Equipment for atomic hydrogen arc welding.

oxygen and nitrogen in the air away and prevents the bad effects that they have on molten metal.

Welds made with atomic hydrogen are more ductile and more easily machined than welds made by other processes. Atomic hydrogen welds are more durable, which makes them better for welding structures subject to deflection and fatigue stresses.

Filler rod may or may not be required, depending upon the type of joint you are working and upon the thickness of the plate forming the joint. Atomic hydrogen arc welding is used for joining thin sheets and light sections made of chrome steel, nickel steel, molybdenum steel, and stainless steel. It is also used to build up or weld non ferrous metals such as aluminum, copper, brass and bronze. Some brasses and bronzes r the use of a flux when they are welded by this process.

RESISTANCE WELDING

Resistance welding is a pressure-welding process in w heat for welding is generated by the resistance to the flo electric current. This is one of the oldest of modern welding processes and it is similar to forge welding in ways (see chapter 12). In forge welding two pieces of me heated in the forge until they reach the plastic stage a welded together with the pressure of repeated blows of a or hammer. In resistance welding, the principle is Two pieces of metal are subjected to a heavy electrical c and because of the resistance to the current the metals become heated to the plastic stage. Pressure is then applied either by hand or mechanically until the two pieces of metal weld together.

THE SPOT-WELDING MACHINE which you will find in shop is an application of this type of welding (se

Spot welding is a pressure process in which the fined to a small portion of the lapped parts to be j heat for this process is obtained from the resistance to the flow of the electric current passing through the joint to be Pressure is applied by a machine through the

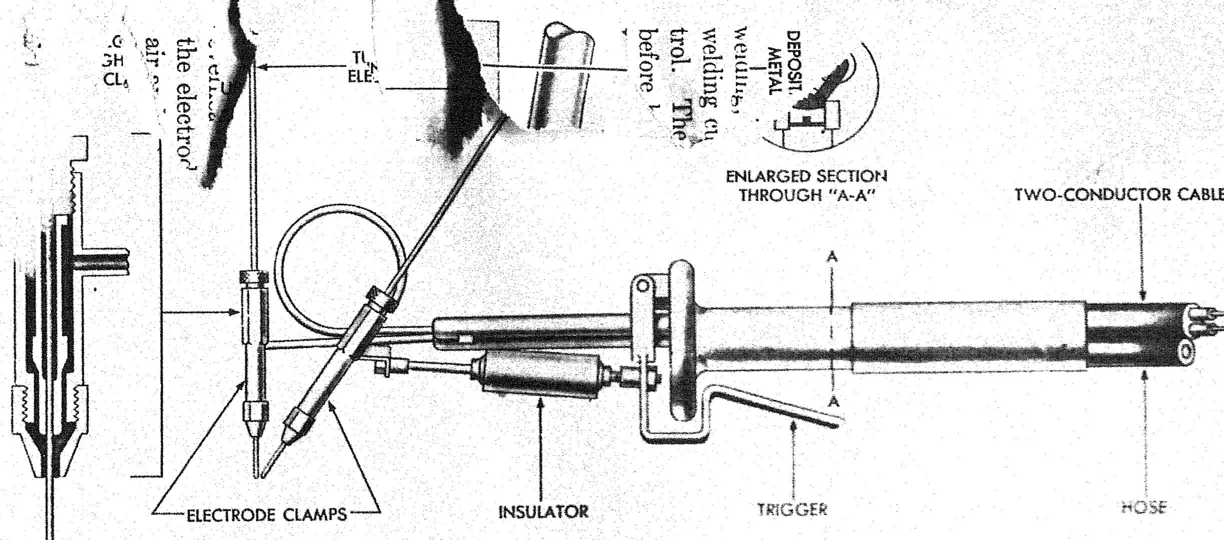


Figure 195.—Electrode holder for atomic hydrogen arc welding.

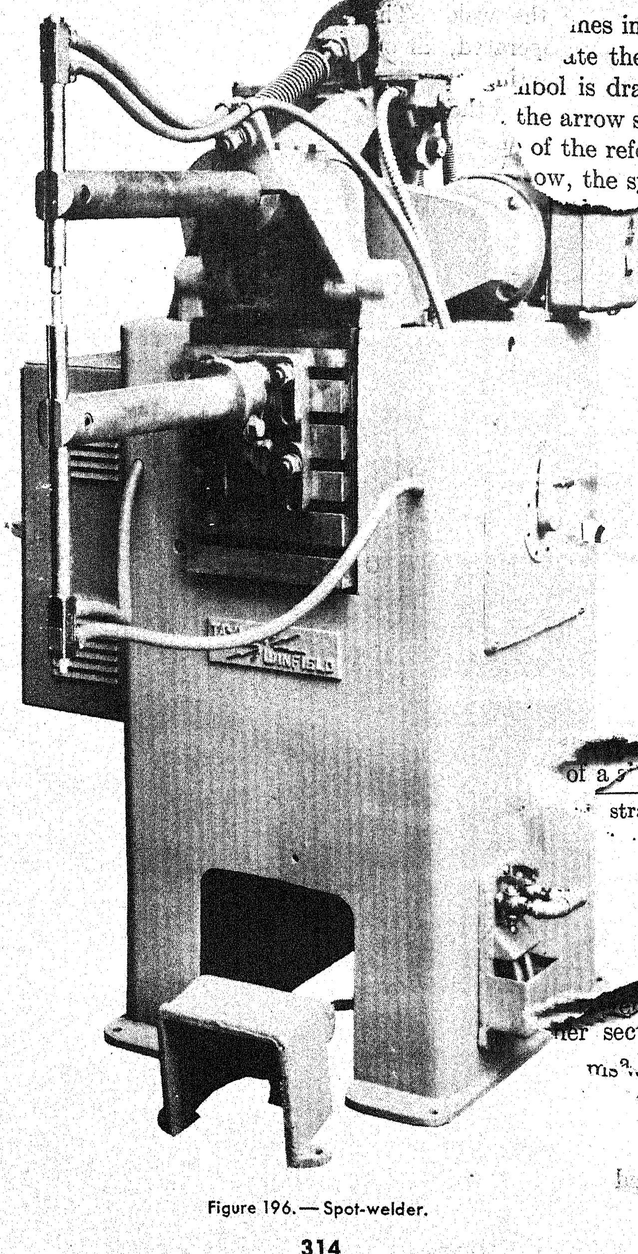


Figure 196.— Spot-welder.

By using ... machines for spot welding are ing of any ... operated, or motor-operated. Con- location of all ... pressure, heat, and time applied are pro- ... spot welder convenient to use when you ... of similar pieces to weld. In many cases ... be used to advantage instead of rivets. Never ... a spot welder without first having been "snapped in" by an experienced operator.

You shouldn't have to be reminded that whatever type of electric welding equipment you're working with, you'll have to be on your toes to keep from grabbing a hot lead. Just remember that the ordinary welding current, under certain conditions, c... cause you plenty of trouble.

Never use any kind of electrical equipment that has its insulation broken or that is "shorted out."

Keep hands off swinging wires—they might be crossed with a "l... wire" somewhere along the line.

Don't experiment with electricity—know what you are doing!

If one of your shipmates is the victim, SHUT OFF THE POWER. Use a dry line or dry board to remove the wire from the man. Your shirt will do, if it is dry. Start artificial respiration immediately and KEEP IT UP FOR AT LEAST THREE OR FOUR HOURS even though stiffening of the body occurs and there is no sign

... lot to learn about welding and it can't all be ... of a book or in the shop. Read a bit and try it out ... then read some more. Watch the experts and imitate their style. Ask intelligent questions and you'll get intelligent answers. Talk the language of the trade and learn to read the language even from symbols and signs.

WELDING SYMBOLS

... ing symbols are used on blueprints and sketches ... kinds of welds to be used. These symbols are standardized by BuShips and apply to both gas and arc welding. You're expected to know them so you can make the welds spec... on blueprints. Study the basic symbols shown in

figure 197. The symbols are placed on horizontal lines in open spaces on the drawing. Arrowhead-tip lines indicate the location of the welds. The line on which the symbol is drawn is known as the reference line. If the weld is on the arrow side of a joint, the symbol is placed on the lower side of the reference line. If the weld is to be made opposite the arrow, the symbol is placed above the reference line. If the weld is to be made at the place of installation after the structure has been fabricated in the shop, the field weld symbol is placed on the reference line.

Sample welds with weld symbols are shown in figure 198. Study these symbols and the welds they represent. They are the ones you'll run into most often.

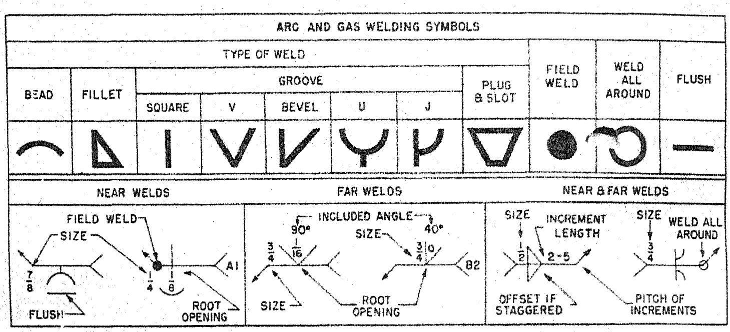


Figure 197.—Basic welding symbols.

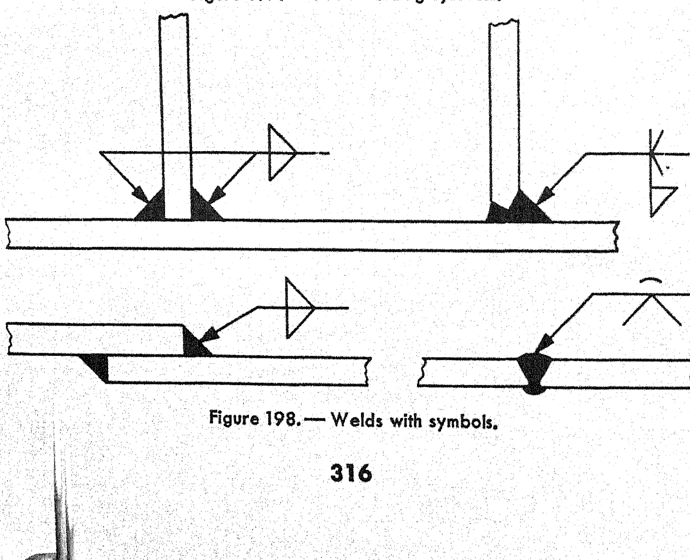


Figure 198.—Welds with symbols.

By using the guide in figure 199 you can figure out the meaning of any unfamiliar symbol. This guide shows the relative location of all symbols that may be used to describe a weld.

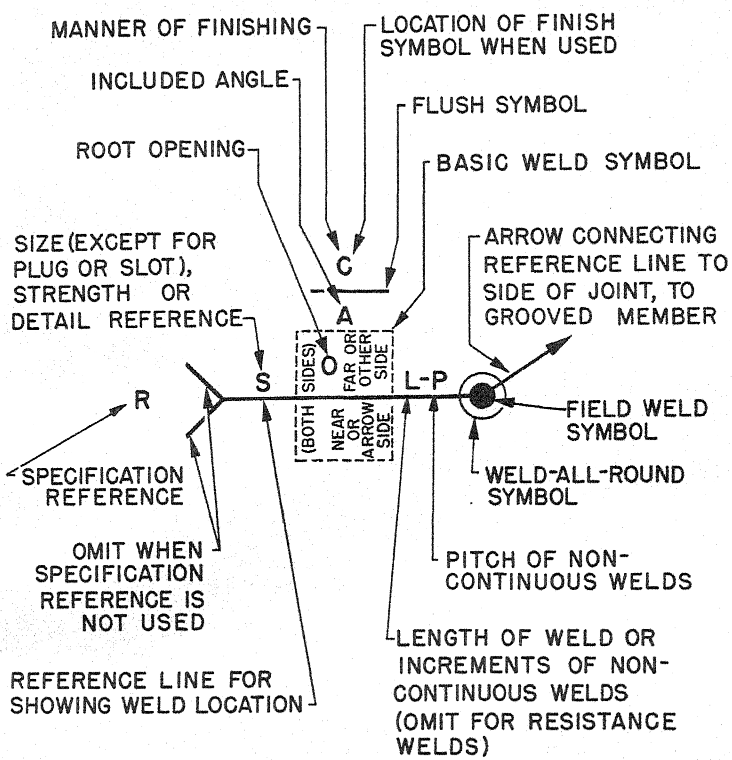


Figure 199.— Guide for reading symbols.

Don't ever forget that the Navy thinks welding is pretty important, and that it has good reason to think so. More important to you, don't forget that you are the guy who is going to do most of the Navy's welding—at least the part of it that is concerned with repair. Soup kettles or battleships, it's your job.

Figure 200. — Soup kettles or battleships, it's your job.

QUIZ

1. Direct current for arc welding is usually supplied by a—
   (*a*) Storage battery system.
   (*b*) Transformer.
   (*c*) Rectifier.
   (*d*) D. C. generator.

2. One purpose of the coatings on some arc-welding electrodes is to—
   (*a*) Improve the stability and characteristics of the arc stream.
   (*b*) Supply a coating of oxidation over the weld.
   (*c*) Eliminate slag.
   (*d*) Decrease the speed of welding in overhead positions.

3. The glass in the arc-welder's face shield must absorb all of the—
   (*a*) Light reflection of the arc.
   (*b*) Arc blow.
   (*c*) Ultraviolet and infrared rays.
   (*d*) Sparks emitted by the process.

4. Brushing is an arc-welding term which describes a method of—
   (*a*) Applying flux to the electrode.
   (*b*) Starting an arc.
   (*c*) Eliminating slag.
   (*d*) Changing polarity.

5. The proper length of an arc can best be judged by—
   (*a*) Looking at it.
   (*b*) The molten which it forms.
   (*c*) The arc's color.
   (*d*) The sound it makes.

6. Penetration at the root of a butt-weld in the flat position may be facilitated by—
   (*a*) Tack welding.
   (*b*) Using a back-up strip.
   (*c*) Placing a seal bead on the back.
   (*d*) Undercutting.

7. The type weld used to make **T**-, lap, plug and slot joints in the flat position is called a—
   (*a*) Fillet.
   (*b*) Tack.
   (*c*) Bead.
   (*d*) Spot.

8. When succeeding beads are to be added, each bead must be cleaned thoroughly of all slag and oxides by—

(*a*) Heating and dipping in borax.
(*b*) Applying a specific acid.
(*c*) Chipping and wire brushing.
(*d*) Adding extra flux.

9. The force which tends to keep molten metal in position in horizontal, vertical, and overhead welds is—

(*a*) Surface tension.
(*b*) Electromagnetic forces.
(*c*) Gravity.
(*d*) Arc blow.

10. When magnetic forces tend to take control of an arc and cause it to become unstable and difficult to handle, it is called—

(*a*) Arc crater.
(*b*) Electromagnetic action.
(*c*) Magnetic repulsion.
(*d*) Arc blow.

11. Resistance welding is classified as—

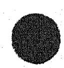
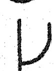
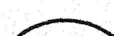
(*a*) Non-pressure process.
(*b*) A pressure process.
(*c*) Fusion welding process.
(*d*) A brazing process.

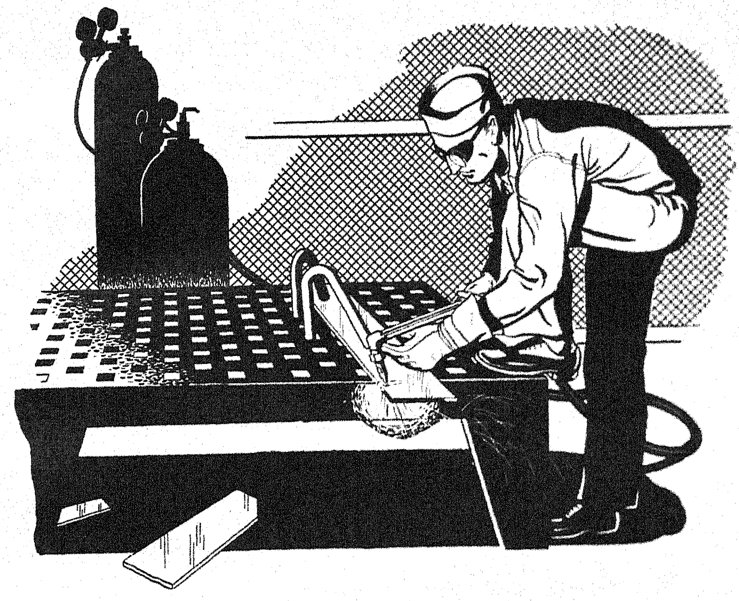
12–22. The symbols in the list *B* are standardized, and apply to both gas and arc welding. Match items in column *A* with column *B*.

A
(Type of weld)

(*a*) Bead.
(*b*) Bevel.
(*c*) Field weld.
(*d*) Fillet.
(*e*) Flush.
(*f*) J.
(*g*) Plug or slot.
(*h*) Spot.
(*i*) Square.
(*j*) Tack.
(*k*) U.
(*l*) V.
(*m*) Weld all around.

B
(Symbols)

12. 
13. 
14. 
15. 
16. 
17. 
18. 
19. 
20. 
21. 
22. 



CHAPTER 10

OXYACETYLENE CUTTING OF METALS

TWO IN ONE

Cutting ferrous metals with an oxyacetylene cutting torch is one of the most amazing jobs that a Metalsmith has. At first, it may be a bit difficult to understand that the oxyacetylene process can be used for both welding and cutting, one being the exact opposite of the other. But the principle that enables you to cut through inches of tough steel in a remarkably short time is not difficult to understand. It is as simple as this: Steel, when preheated to the kindling temperature range (1400°F. to 1600°F.), burns very rapidly in an atmosphere of pure oxygen. So when you direct a jet of pure oxygen on red-hot steel, a chemical reaction takes place. This chemical reaction forms iron oxide and gives off a lot of heat. The heat is sufficient to melt the iron oxide and some free iron which

runs off as molten slag, exposing more iron to the jet. It might be said that the burning or oxidizing process is an extremely rapid rusting, the rust being formed in the molten state.

Only that metal which is in the direct path of the oxygen jet is acted upon. When steel is cut, a narrow slit or race is formed. This opening is commonly called a kerf. Actually, the steel or iron removed from the kerf is only about 60 to 70 percent oxidized by the oxygen and the remainder is blown or washed out of the cut as metallic iron.

While making the cut, you'll have to keep the preheating flames of the cutting torch burning so that the kerf will progress

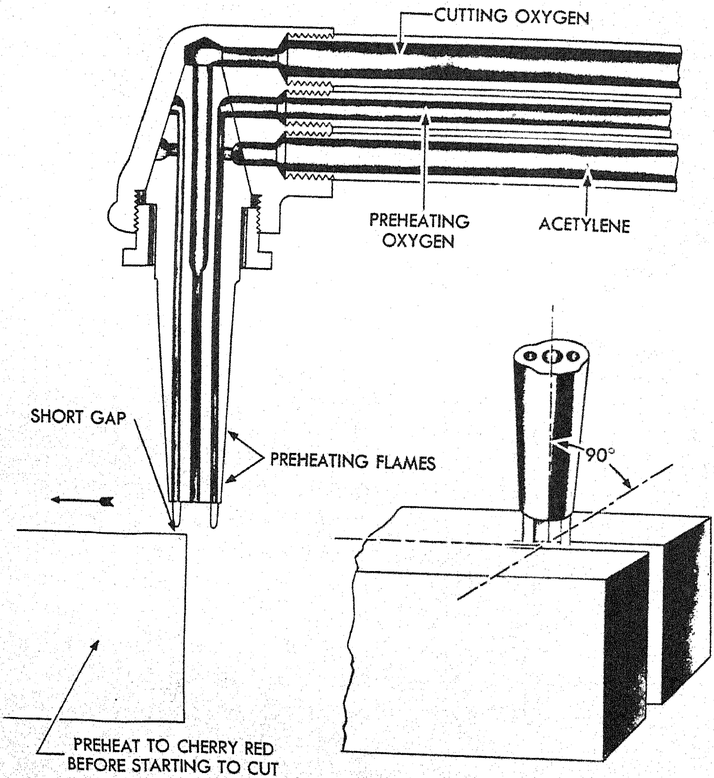


Figure 201.—Starting a cut and cutting with a cutting torch.

smoothly. The heat generated by the chemical reaction should be sufficient for preheating the metal; but because of the rapid radiation caused by dirt, scale, and paint, preheating is necessary.

The walls of the kerf formed by oxyacetylene cutting of ferrous metals are fairly smooth and are parallel to each other. When you develop skill in the handling of your torch, you'll be able to hold your cut to within reasonably close tolerances, and to guide it along any desired line, whether straight, curved, or irregular. You'll also be able to hold your torch at an inclined angle for cutting bevels.

THE CUTTING TORCH

The cutting torch looks a lot like the welding torch, but it is used to separate pieces of metal rather than to join them. It has an extra tube for high-pressure oxygen which can be controlled from a valve on the handle. In the regular cutting torch, the valve may be in the form of a trigger assembly like the one in figure 202.

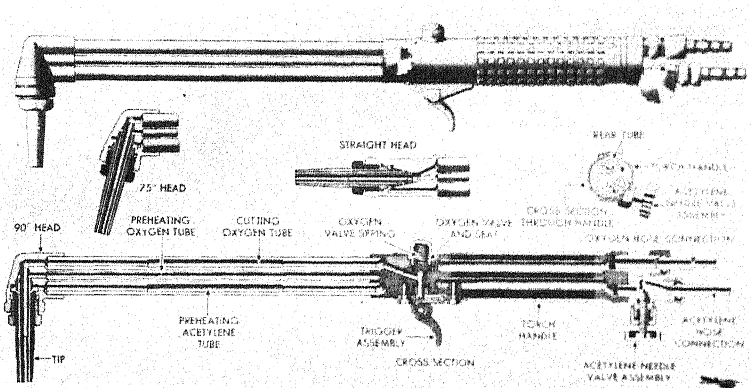


Figure 202. — The cutting torch.

Some welding torches are furnished with a cutting attachment which may be fitted to the torch in place of the welding head. Such an attachment serves the same purpose as the cutting torch. On torches of this type the high pressure

oxygen is controlled by a lever on the handle like the one in figure 203.

Whether you use a cutting torch or a cutting attachment, you'll notice that the nozzle or tip is made in the same way.

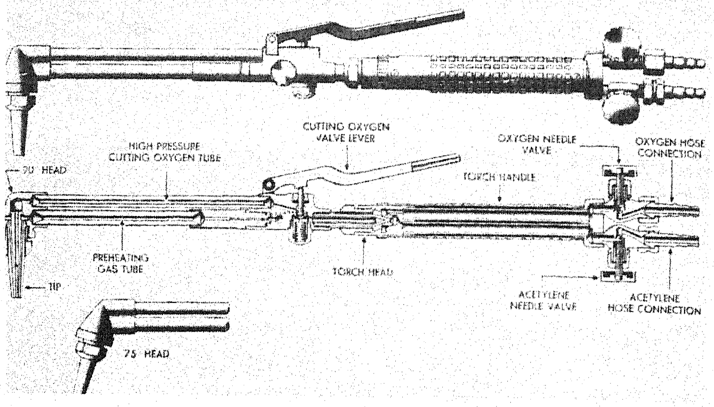


Figure 203.—Cutting attachment for a welding torch.

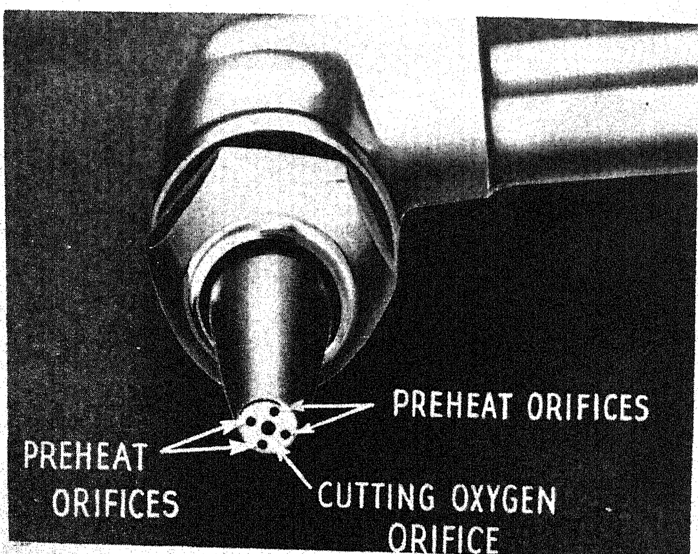


Figure 204.—Orifices in the cutting tip.

The cutting tip or nozzle is made with a number of orifices (holes). The jet or stream of oxygen that does the cutting comes from the center orifice. The smaller orifices surrounding the center orifice are for oxyacetylene heating flames. These are used for preheating the metal to the kindling temperature.

OPERATING CUTTING EQUIPMENT

Attach the proper cutting tip for the thickness of the metal to be cut to your cutting torch and adjust the oxygen and acetylene pressure. Be sure to check the manufacturer's instruction for pressure adjustments for the particular type of torch that you are using. The following table will serve, however, as a general reference for tip sizes and oxygen and acetylene pressures for cutting plates of various thicknesses.

SUGGESTED CUTTING TABLE

Plate Thickness	Tip Size No.	Acetylene Pressure lbs. per sq. in.	Oxygen Pressure lbs. per sq. in.
¼-inch	0	3	25 to 30
⅜ to ½-inch	1	3	30 to 40
¾ to 1-inch	2	3	40 to 50
1½-inches	3	3	45 to 50
2 inches	4	3	50 to 55
3 to 4 inches	5	4	50 to 65
5 to 6 inches	6	5	55 to 60
8 to 10 inches	7	6	60 to 70
12 inches	8	6	70 to 80

Adjust the preheating flames to neutral. Hold the torch perpendicular to the work with the inner cones of the preheating flames about $\frac{1}{16}$ inch above the end of the line to be cut. Hold the torch still in this position until the spot that you are heating has been raised to bright red heat. Open the oxygen valve slowly but steadily. If your cut has started properly, you'll see a shower of sparks fall from the opposite side of the work, indicating that the cut is going all the way through. Move your cutting torch forward along the line just fast enough for the cut to continue to penetrate the work completely. If you've made your cut properly, you'll get a clean, narrow cut which

looks somewhat like one you might make by sawing. If you are cutting round bars or heavy sections, you can save time and gas if you raise a small bur with a chisel where the cut is to start. This small raised portion will heat quickly, and cutting will start immediately. A steel welding rod can also be used as an aid to start a cut on a heavy section. When a welding rod is used for starting a cut, it is called a cutting rod.

If you have a cut to start from the center or some portion of metal other than the edge, use the following method for starting the cut. Preheat the spot on the surface where your cut is to start to a bright red. Tilt your torch at an angle of about 45° from the perpendicular in line with the direction of the cut. Open your high-pressure oxygen valve very slowly. As the torch begins to cut, start righting it to a perpendicular to the surface of the plate. Continue to right the position of the torch gradually as it cuts until it is at 90° to the surface of the plate and is cutting all the way through the plate. Move it forward along the line of cut as fast as complete penetration can be accomplished. If you do not follow this procedure you are likely to blow the slag back on your cutting tip, clogging the orifices or otherwise damaging your equipment.

When you have started a cut, move the torch slowly along the cutting mark or guide. As you move along, keep an eye on the cut so you can tell how it is progressing. Make torch adjustments if necessary. You'll need to move along at just the right speed—not too fast and not too slow. If you go too slow, the preheating flame will melt the edges along the cut. It may even weld them back together at the surface. If you go too fast, the oxygen will not penetrate completely through the metal and the cut will be incomplete. In that case, you'll have to close the cutting oxygen valve and go back, preheat, and make a new start at the beginning of the partially cut area.

Try to make the cut as smooth as you can. Anyone who can light the torch can cut steel after a fashion, but it takes a sharp Metalsmith to get a smooth cut every time. If the cut isn't perfect, check up on the following points:

1. Preheating Flames—If the preheating flames are too short,

the cut will have a gouged appearance at the bottom. If too long, the top edge of the cut will be fused.

2. Oxygen Pressure—If the oxygen pressure is too low the top edges will be melted. If it is too high, the cut will be extremely rough and irregular.
3. Cutting Speed—If the cutting speed is too slow, the drag lines are irregular. If it is too fast the drag lines are rough and they form sweeping curves. (Drag lines are the marks left on a cut edge. A good cut shows smooth, vertical, uniform marks which are continuous from the top surface to the bottom surface.)

CUTTING BEVELS

You'll have occasion to cut bevels quite often to form joints for welding. To make a bevel cut of 45° in 1-inch steel, the flame must actually cut through 1.4 inches of metal. Consider

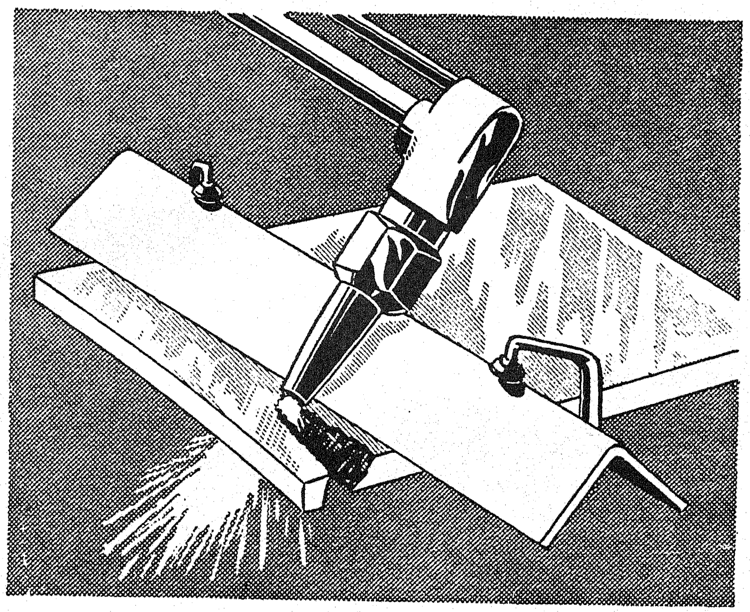


Figure 205.—Bevel cutting.

this when you are selecting the tip and adjusting the valves. You'll have to use more pressure and less speed for the bevel cut than for a straight cut.

When you're going to do bevel cutting, adjust the tip so that the preheating orifices are lined up for efficient preheating. A piece of 1-inch angle iron, clamped with the angle up, makes an excellent guide for beveling straight edges. Pull the torch along this guide as shown in figure 205.

If you are aboard a repair ship or a tender you'll have a cutting machine something like the one in figure 206. This is a motor-driven cutting machine designed to support the cutting torch and guide it along the line of cut. It may be set to make uniformly clean cuts or bevels on steel plate. Straight-line

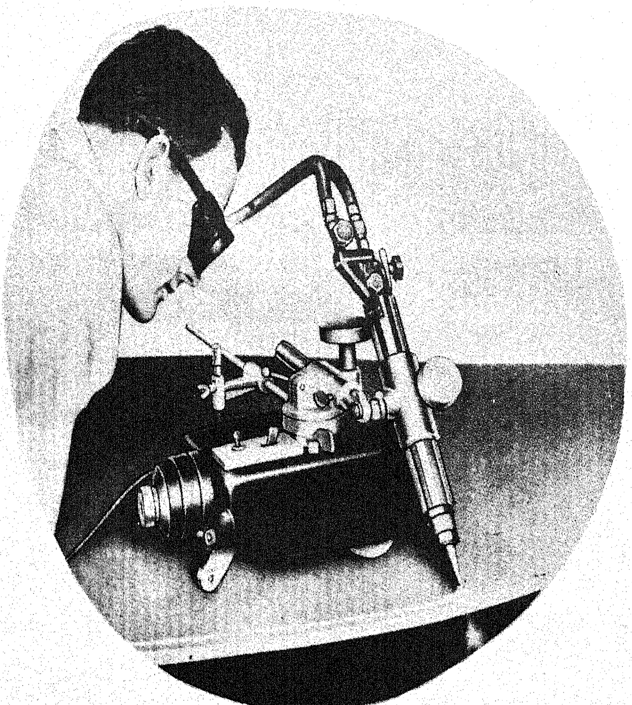


Figure 206.—Making a bevel cut on a circular path with a special cutting machine

cutting or beveling is done by guiding the machine along a straight line on steel tracks. Arcs and circles are cut by guiding the machine with a radius rod pivoted about a center point.

PIPE CUTTING AND BEVELING

When you're cutting off a piece of pipe, keep the torch pointed toward the center line of the pipe. Start the cut at the top and cut down one side. Then begin at the top again and cut down the other side, finishing at the bottom of the pipe. The process is shown in figure 207.

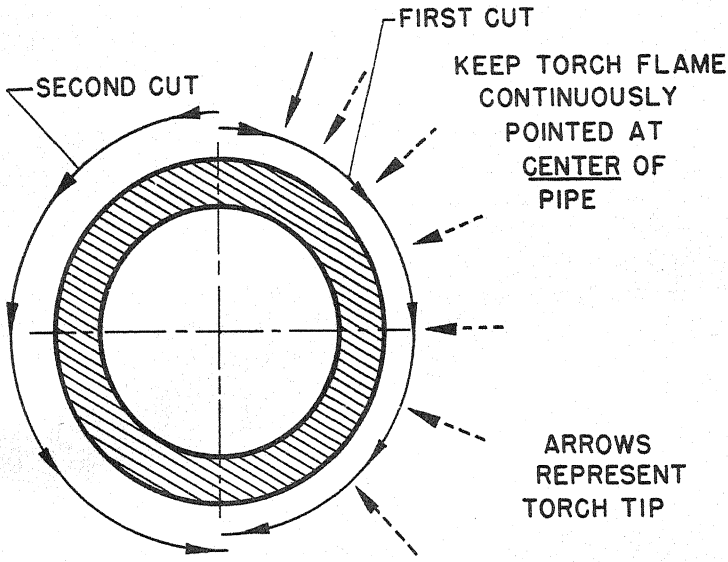


Figure 207.—Cutting pipe with the oxyacetylene cutting torch.

Pipe cutting with the cutting torch requires a steady hand to get a good bevel—one that is smooth and true. Don't try to cut and bevel a heavy pipe in one trip. Cut the pipe off square first, then bevel it. This makes a cleaner and better job.

Check the alignment of your torch-tip preheating orifices before you start to work on pipe. Arrange these orifices in line with the cut.

Your cutting torch is also a valuable tool for piercing holes in steel plate. To pierce a hole in steel plate follow the directions given here. Lay the plate out on two firebricks in such a manner that the flame won't hit something else when it burns through. Hold the torch over the hole location with the tips of the inner cone of the preheating flames about ¼ inch above the surface of the plate. Continue to hold the torch in this position until a small round spot has been heated to a bright red. Open the high pressure oxygen valve very gradually and at the same time raise the nozzle away from the work slightly to keep from blowing slag back into the cutting tip. As you start raising your torch and opening the oxygen valve, start rotating the torch with a spiral motion. This will cause the molten slag to be blown out of the hole. The hot slag may fly around, so be sure that your goggles are well fitted to your eyes and face and avoid having your head directly above the cut.

Now if the hole that you need is of a larger size, just follow the procedure outlined above after outlining the edge of the hole with a piece of chalk. Start the cut from the hole that you have pierced by lowering the preheating flames to the normal

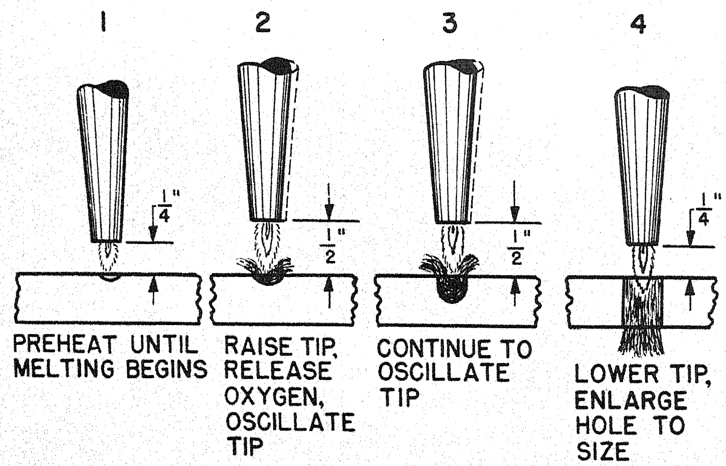


Figure 208.—Piercing a hole.

distance and working to and following the line that has been drawn on the plate. Truly round holes can be made by using a circular torch with a radius bar attachment.

RIVET CUTTING

When you have a job of removing rivets from plates that are to be disassembled, you'll find your cutting torch a good tool to have around again. Just use the preheating flames of your cutting torch to bring the head of the rivet up to its critical temperature, then turn on the oxygen and wash the head off. The remaining portion of the rivet can then be punched out with a light hammer blow. Here it is step by step:

1. Use the size tip and oxygen pressure that you would use for 1-inch steel.
2. Heat the rivet head until it is bright red.
3. Then move the tip to a position parallel with the surface of the sheet and turn the cutting oxygen on slowly.
4. Cut a slot in the rivet head like the screw-driver slot in a roundhead screw.
5. When the cut nears the plate, draw the nozzle back at least 1½ inches from the rivet. This is important.
6. When you have cut the slot through to the plate, swing the tip through a small arc. This slices off half the rivet head.
7. Then swing the tip in an arc in the other position to slice off the other half of the rivet head.

After the slot is cut, you won't have to worry about preheating the rest of the rivet head to cutting temperature. Just before you get through the slot to the surface of the plate, you draw your torch tip back an inch and a half to allow the cutting oxygen to scatter slightly. This keeps the torch from breaking through the layer of scale that is always present between the rivet head and the plate. It allows the head of the rivet to be cut off without damaging the surface of the plate. If you don't draw the tip away, you may cut through the film of scale.

If you have access to a low-velocity cutting tip, you'll find it 50 per cent faster for cutting buttonhead rivets and about the

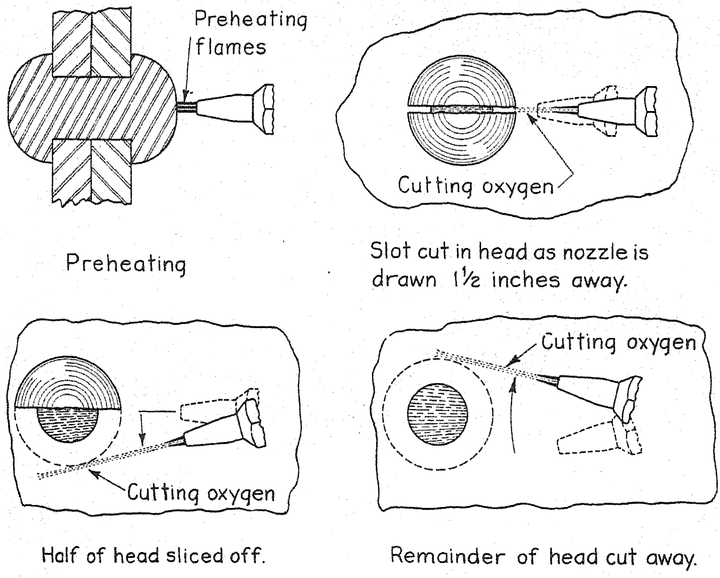


Figure 209.— Manipulating the cutting torch to remove the head of a rivet.

only satisfactory way of removing countersunk rivets. A low-velocity rivet cutting tip has a cutting-oxygen orifice with a large diameter. Above this orifice are three heating orifices. You should always place a low-velocity cutting tip in the torch so that the heating orifices are above the cutting orifice when the torch is held in the rivet-cutting position.

When you get a job of removing countersunk rivets from vertical sheets, follow these instructions for best results:

1. Hold the torch horizontally and turn it so that the tip also points horizontally.
2. Tilt the tip upward about 15° and hold the heating flame on a point slightly below the center of the rivet head.
3. When you get the area heated to a dull red, move the torch upward, still keeping the upward tilt, and open the oxygen-cutting valve.
4. Hold the torch steady with the cutting stream directed at the center of the rivet. As the rivet is cut away, the

angle of the torch should be decreased until the tip is perpendicular to the sheet or plate, and the cutting stream directed at the center of the rivet.

5. When you have cut through the head to the shank of the rivet, wash away the remainder of the head with one circular wiping motion. Always move the torch so that the cutting stream will follow the preheat.
6. The shank may then be removed by a light tap with a hammer and punch.

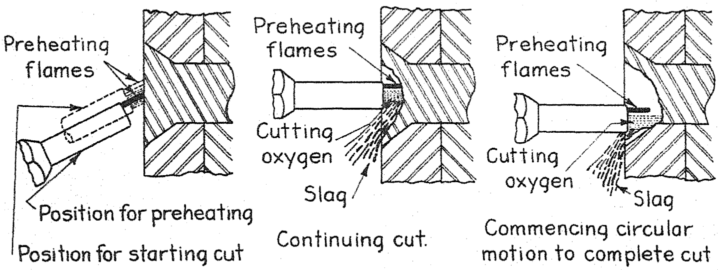


Figure 210.—Cutting a countersunk rivet with a low-velocity tip.

Buttonhead rivets may be removed in the same manner as countersunk rivets with the low-velocity cutting nozzle. The process is illustrated step by step in figure 211. Remember that it is very important to start below the center of the head, as this will allow the molten metal to run down or out from below and leave the metal being cut free from slag.

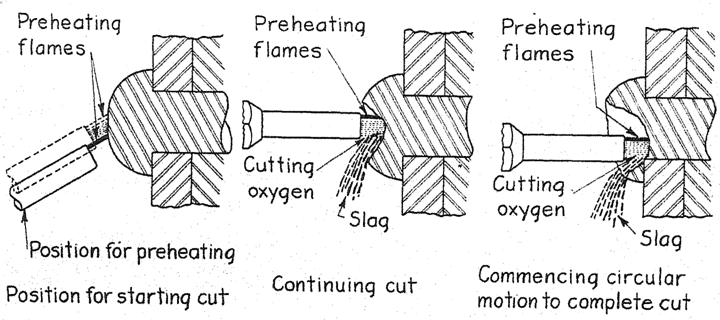


Figure 211.—Cutting buttonhead rivets with the low-velocity tip.

Plain carbon steel—steel in which the carbon content isn't over 0.35—can be cut without a lot of precautions. You need only to observe those precautions required for cuts in iron or steel of good quality.

For higher carbon and alloy steel, you'll have to take precaution to prevent the formation of a hard layer at the edges of the plates. This is more likely to be true when you're cutting so-called air-hardening steels, since a thin layer of metal at the cut edge is heated to its critical temperature and rapidly quenched by the adjacent plate and the surrounding air. The edges are hardened in this manner, they are difficult to machine and are less ductile. Their lower ductility may even cause cracking under load. To avoid forming this hard layer around the edges, you should preheat the edges ahead of the cut. Preheating temperatures of from 500° F. to 600° F. are sufficient to lower the rate of quench and should be used when cutting high carbon and alloy steels.

Stainless steel cutting is not an oxidation process like iron and steel cutting—it is a melting process. Stainless steels are designed to resist oxidation and are therefore difficult to cut with the oxyacetylene cutting torch. The best way to cut stainless steel is to lay a steel welding rod or steel plate along the line of cut. The heat developed by the reaction of the oxygen with the steel rod or plate is enough to melt a slot in the stainless steel and thus produce the cut.

Cast iron is more difficult to cut than steel because it melts at a lower temperature than does its oxide. When cast iron melts, the oxide mixes with it. This means that cast iron must be preheated to a much higher temperature than steel, and also means that you'll have to use an oxygen pressure of from 25 to 100 percent greater than you will for steel of the same thickness. Adjust your preheating flame to carburizing so that the length of the feather of acetylene will be equal to the thickness of the cast iron that you are to cut. Start the cut with your torch tip forming an angle of 75° to 80° with the surface of the casting. As your cut progresses, gradually right the torch tip

to an angle of 90° to avoid losing your cut. Move your torch forward in the direction of the cut just fast enough to sweep the edge of the cut. If you advance too deeply, progress of the cut will cease and black spots will develop under the cutting jet. From the beginning of the cut until it is finished, hold your torch tip 1½ to 2 inches from the surface of the cast iron. Move your torch tip ½ to ¾ inch in a semicircular weaving motion, as required to clear the cut in heavy sections. Lighter sections won't require so wide movements to keep the cut clear.

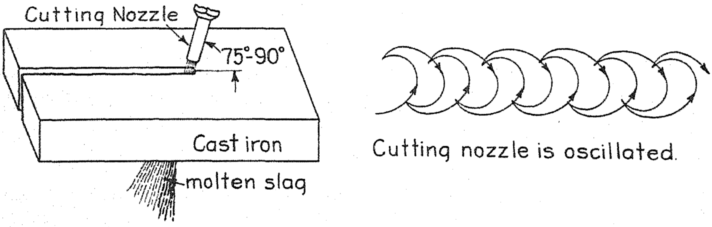
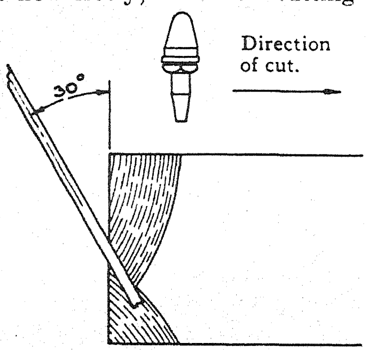


Figure 212.—Cutting cast iron.

FLUX CUTTING is a method used on metals that are difficult to cut, like poor grade cast iron. With such metals as cast iron, the slag does not flow freely, and their cutting can be made



Approximate introduction angle of flux rod or lance to assist cutting operation.

Figure 213.—Flux cutting.

easier by mixing the slag with that of a metal that is easily cut, or with other substances that will produce the same result. Thus, if you feed a steel welding rod or an iron bar into the cut, you'll increase the fluidity of the slag and make the cast iron easier to cut.

Another type of flux cutting is used in cutting 18-8 chrome-nickel plate. You simply place the alloy plate between a couple of plates of plain carbon steel. Try this method, especially if you are trying to get good sharp corners on your 18-8 plate.

CLEANING THE TIP

You've been warned about holding the tip too close to the surface of the metal when starting a cut. The blowing action of the oxygen blast tends to bounce the molten metal and slag from the cut back up to the torch tip. If it does, and it will, you'll have to clean the tip orifices often. Use the proper size tip-cleaning drills for this purpose—not some improvised makeshift—or you'll have the orifices enlarged and the tip ready for survey. A tip drill is a small drill which may have a hex-nut head, a round head, or plain shank. Use it by pushing it into the hole—don't rotate it. Be sure you have the right size. If the end of the tip does become rough and pitted and the orifices become oversize (bell-mouthed), you can recondition the tip in this manner: Place a piece of emery cloth, grit side up, on a flat surface. Hold the tip perpendicular to the emery cloth and rub it back and forth just enough to true the surface and bring the orifices back to their original diameter.

After you clean the tip, test it by lighting and observing the preheating flames. If the flames are too short, the gas passages are partially blocked. If the preheating flames snap out when the valves are shut, the orifices are still bell-mouthed and the tip needs further working down to bring them back to their original size.

If the tip seat is dirty and scaly so that it fits the torch head imperfectly, heat it to a dull red and quench it in water. This loosens the scale and dirt enough so that you can easily rub them off with a cloth.

Ordinarily the responsibility for making an emergency cut won't be left up to you. You'll make the cut only when ordered to do so by an officer or senior petty officer.

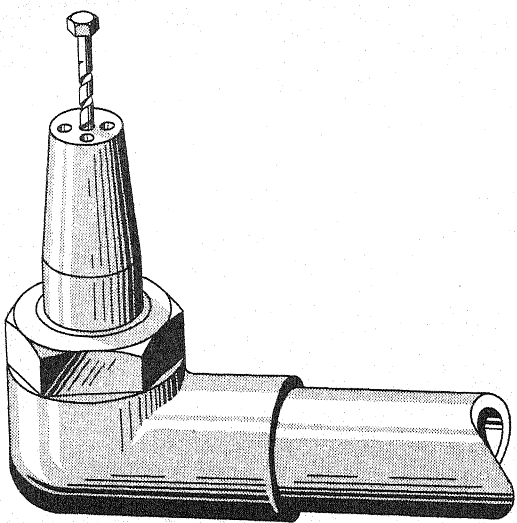


Figure 214.—Cleaning the tip.

The cutting torch is used sometimes as a last resort to cut open doors and other closures that are jammed. If you are on your own, try all other measures before you use the torch. Don't use the torch until you're sure you know what is on the other side of the bulkhead or deck. BEWARE OF OILS AND GASES. Use an explosimeter to test the air.

When you make an emergency cut, station fire fighters equipped with CO_2 extinguishers, where they can immediately quench any fire that might break out.

If you are cutting through a bulkhead to free trapped men, cut the hole only large enough for a man to crawl through. If gear has to be carried through, the hole can easily enough be enlarged. Watch out for structural members and avoid them.

You'll find portable oxyacetylene cutting outfits kept in damage control lockers. These outfits are arranged so that they can be used on a minute's notice.

PRECAUTIONS

The cutting torch is a valuable tool; it is also a dangerous tool if used carelessly. Treat it with respect.

In all cutting operations, you must be especially careful that hot slag does not come in contact with any combustible material. Hot globules of slag will roll along the deck for considerable distances. Don't leave any combustible materials lying around closer than 30 or 40 feet. If you can't move the material, cover it with sheet-metal guards or asbestos paper. Be sure that your acetylene cylinders are clear and far enough away so that hot slag won't fall on them.

If you have to cut painted metal, use a mask that will supply you with fresh air so that you won't have to breathe fumes. (A GAS MASK WILL NOT WORK HERE.)

THE OXYGEN LANCE

You'll be hearing about the oxygen lance, though you probably won't be using it much. The oxygen lance is nothing more than a piece of ¼-inch or ⅜-inch standard black iron pipe hooked up to a source of oxygen which you control with

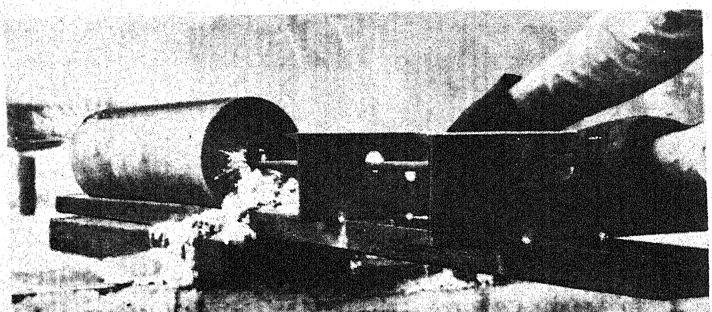


Figure 215.—Using an oxygen lance to pierce a hole through a 30-inch length of chrome-nickel steel shafting.

a suitable valve. You use a separate torch to bring the metal up to the kindling temperature, and then bring the end of the lance (pipe) up to the heated area and turn about 40 to 60 pounds per square inch of oxygen on the heated metal. The ferrous metal is burned and produces enough heat to keep the cutting action going without the use of separate heat. The oxygen lance, like the oxygen cutting torch, cannot be used economically for the cutting of nonferrous metals and is therefore restricted in most cases to cutting ferrous metals.

ELECTRIC ARC CUTTING

Electric arc cutting is a melting process. The heat of the arc is used to melt the metal along the line of cut. This method of cutting doesn't produce as good quality cut as do the other methods, but it can be applied to almost all metals. Arc cutting can be used to cut all ordinary ferrous metals including alloy steels and cast iron. You can also cut all types of nonferrous metals with the arc, which gives it a definite advantage over flame or oxygen cutting.

Arc cutting can be done with either a carbon or graphite electrode or with a shielded-arc metallic type of electrode. Figure 216 illustrates the procedure for arc cutting. The cut is made wide in order to work away the metal in the kerf. You can make a cut in the vertical position, but the horizontal position works best. The position of the plate will determine the angle of the electrode. When you are cutting heavy plate, work your electrode from the bottom to the top of the plate with the bottom slightly ahead of the top (see figure 216).

Whether you are using the carbon or the shielded arc electrode for cutting, you use straight polarity (electrode negative), and a long arc. You'll have to set your current and voltage much higher than for welding, and you may even have to have special electrode holders to resist the high heat that will be developed.

You can also use the electric arc for rivet cutting and hole piercing. The shielded-arc electrode is better than the carbon arc for these jobs just as it is better for cutting through heavier sections.

This is because the coating acts as an insulator a 'y. Don't the arc from shorting against the sidewalls of the ho. Also the electrode coating extends beyond the me... ..., making it possible for you to push the electrode against the plate or rivet without shorting out.

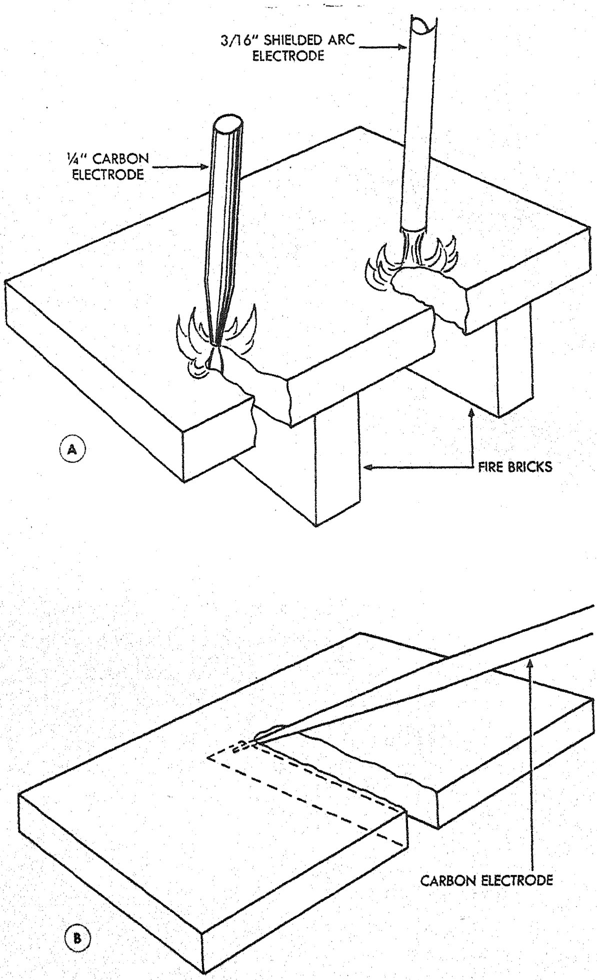


Figure 216.—Carbon and shielded-arc cutting.

3. The st[illegible] tip [illegible]

YOU WANT TO RETIRE ON THIRTY?

. plan to retire on thirty, there are a few simple little precautions that you must not forget even once, when you are working with welding or cutting equipment. Don't guess—don't experiment—don't assume anything. Be sure you're right before you start to weld or cut. You may not have a second chance if you don't do it right the first time.

If you keep the following rules in mind, your chances of being around will be a lot better:

1. Use no oil or grease on any welding or cutting equipment.
2. Use a spark lighter to light your torch. Do not use matches.
3. Open the acetylene valve about one-quarter of a turn to light an oxyacetylene torch. Don't light it with both valves open.
4. Be sure there are no leaks in your oxyacetylene equipment. Don't use leaky equipment.
5. Test for leaks with soapy water and a brush—not with a flame.
6. Keep the kinks out of your welding hose.
7. Wear proper protective clothing at all times when welding or cutting, even if it is a small job. Hot metal from a little job will burn just as much as hot metal from a big job.
8. The people working near by or watching you are your responsibility. See that they are also protected.
9. Hang torches and electrode holders in their proper places—not on your regulators.
10. Welding or cutting fuel containers is dangerous—it can be done by using live steam or other precautionary measures to clear the container of all explosive gas.
11. Provide yourself with a standby fire watch when you are welding or cutting.
12. When you are working in a confined space, station a man at the bottle valves.
13. Use tools made for the job. Don't improvise makeshift tools.

14. Replace unsatisfactory equipment immediately. Don't try to repair valves and regulators.
15. Baby those cylinders—it doesn't pay to get rough with them.
16. Check your ventilation. Don't weld or cut in a confined space.
17. Never strike an arc on a cylinder—it just isn't done.
18. Striking an arc on any sealed container is asking for trouble.
19. Dropping hot, rejected electrode studs on the deck is not good practice.
20. All checking of circuits on welding machines should be done on dead circuits. Get an Electrician's Mate to check any serious trouble.
21. The polarity switch should never be operated when the welding machine is working under load. Operate your polarity switch while the machine is still or idling.
22. If you are using a motor-generator type of arc-welding machine, be sure you have a power ground on the machine.
23. Never look at an electric arc with the naked eye.

These are some of the more important precautions you will need to keep in mind. If you are not sure about something, find out from a reliable source. Most important of all—THINK! Davy Jones' Flotilla is manned by guys who didn't think! They didn't retire on thirty.

QUIZ

Select the one best answer to each of the following statements.

1. The process of severing ferrous metal by means of the chemical action of oxygen on the elements in the base metal is called—
   (*a*) Carbon arc cutting.
   (*b*) Flame treating and cutting.
   (*c*) Metal arc cutting.
   (*d*) Oxyacetylene cutting.

2. The jet coming from the center orifice of a cutting torch tip will be—
   (*a*) Acetylene.
   (*b*) Oxygen.
   (*c*) Carbon Dioxide.
   (*d*) Hydrogen.

3. The streams coming from the smaller orifices surrounding the center tip orifice are for—
   (*a*) Cutting.
   (*b*) Postheating.
   (*c*) Preheating.
   (*d*) Oxidizing.
4. In torch cutting a plate ⅞ inch thick, the recommended tip size number would be—
   (*a*) 0.
   (*b*) 1.
   (*c*) 2.
   (*d*) 3.
5. Acetylene pressure in relation to oxygen cutting pressure must be—
   (*a*) Much lower.
   (*b*) Much higher.
   (*c*) The same.
   (*d*) Alternately higher, then lower.
6. The preheating flames of a cutting torch should be adjusted to—
   (*a*) Reducing.
   (*b*) Oxidizing.
   (*c*) Normalizing.
   (*d*) Neutral.
7. In starting a straight cut on metal other than an edge, tilt torch at a 45° angle from perpendicular in line with the direction of cut in order to—
   (*a*) Provide proper starting bevel.
   (*b*) Eliminate slag blow back.
   (*c*) Preheat properly.
   (*d*) Eliminate spark shower.
8. If a preheating cutting flame is too long, the—
   (*a*) Cut bottom will have a gouged appearance.
   (*b*) Cut will be extremely rough and irregular.
   (*c*) Drag lines will be irregular.
   (*d*) Cut's top edge will be fused.
9. If oxygen pressure is too low in torch cutting, the—
   (*a*) Bottom of cut will appear gouged.
   (*b*) Top edges will be melted.
   (*c*) Drag lines form sweeping curves.
   (*d*) Drag lines are irregular.
10. A good cutting speed with the cutting torch will produce—
   (*a*) Uniform drag lines forming sweeping curves.
   (*b*) Irregular drag lines.
   (*c*) Continuous vertical drag lines.
   (*d*) Very little spark shower.

11. A suitable torch guide for cutting beveled straight edges is a—
   (*a*) Protractor bevel, with extension.
   (*b*) 1-inch angle iron, with angle up.
   (*c*) Special tip with steel guides.
   (*d*) A chalk line

12. The best way to cut off and bevel a piece of pipe is to—
   (*a*) Make a continuous cut around the pipe.
   (*b*) Hold tip at a 45° angle with center of the pipe.
   (*c*) Oscillate cutting tip.
   (*d*) Cut off square, then bevel.

13. The purpose of rotating the torch when piercing a hole is to—
   (*a*) Blow molten slag out of the hole.
   (*b*) Insure a round hole.
   (*c*) Distribute cutting heat evenly.
   (*d*) Insure proper preheating.

14. The cutting tip for removing countersunk rivets should—
   (*a*) Have a small diameter oxygen orifice.
   (*b*) Have four flame heating orifices.
   (*c*) Be low-velocity.
   (*d*) Be high-velocity.

15. To avoid forming a hard layer along the edges when torch cutting high carbon and alloy steel—
   (*a*) Preheat edges ahead of cut.
   (*b*) Postheat edges after cut.
   (*c*) Use an oil bath for quenching.
   (*d*) Smear edges with a grinder.

16. The process of cutting stainless steel is known as—
   (*a*) Deoxidizing.
   (*b*) Carburizing.
   (*c*) Oxidation.
   (*d*) Melting.

17. Laying a steel rod along the cut line is a definite aid in cutting—
   (*a*) Low carbon steel.
   (*b*) Stainless steel.
   (*c*) Cast iron.
   (*d*) High carbon steel.

18. Cast iron is more difficult to cut than steel because—
   (*a*) Steel must be preheated to a higher temperature than cast iron.
   (*b*) It requires a much smaller oxygen pressure than steel.
   (*c*) It melts at a lower temperature than its oxide.
   (*d*) It is more brittle than steel.

19. Flux cutting is the—
   (a) Adding of a non-corrosive flux ahead of the torch.
   (b) Feeding a steel welding rod into the cut.
   (c) Fluxing of the line of cut prior to preheating.
   (d) Fluxing the cut to prevent oxidation.

20. A cutting torch tip should be cleaned with a—
   (a) Mixture of borax.
   (b) Steel wool.
   (c) Steel brush.
   (d) Drill.

21. Too short a flame after cleaning a tip will indicate that the—
   (a) Orifices are bell mouthed.
   (b) Tip seat is dirty and scaly.
   (c) Gas passages are partially closed.
   (d) Oxygen orifice is plugged.

22. If necessary to make an emergency oxyacetylene cut, the air should be tested with—
   (a) An explosimeter.
   (b) A spark igniter.
   (c) A match.
   (d) A barometer.

23. The most suitable way to pierce a hole through a long shaft would be to use—
   (a) An oxyacetylene cutting torch.
   (b) A metal lathe.
   (c) A heavy duty drill press.
   (d) An oxygen lance.

24. The angle of an electric arc cutting electrode will be determined by the—
   (a) Thickness of plate being cut.
   (b) Position of plate being cut.
   (c) Amount of voltage available.
   (d) Type of metal being cut (ferrous or non-ferrous)

25. The best test for leaks in oxyacetylene torch lines is the use of—
   (a) A match.
   (b) Compressed air.
   (c) Soap suds.
   (d) Test paste.

CHAPTER 11

SHEET METAL MEASUREMENT AND LAYOUT

All your life you have come in contact with a lot of things made of SHEET METAL. The gutters and downspouts that the local "TIN BENDER" put on the new house down the street, the system of furnace piping that carried the air that warmed your home in winter, funnels you have used to pour gasoline in your jalopy—yes, even the cookie cutters your mother used to use—were made of sheet metal. These and hundreds of other items are made of sheet metal. Aboard your ship you will be called upon to fabricate many items similar to those you have seen around your own home. Have you ever stopped to think how those items were LAID OUT, fabricated, and installed? Before you can install the item you have to construct it. Before you

can construct it, you'll have to lay out your work. Before you can do any of these things you'll have to be able to measure lengths, widths, thicknesses, and angles with a great degree of accuracy. Unless your measurements are "right on the button," you will not be able to construct the desired shape.

LAYOUT TOOLS

The tools you'll most often use in laying out sheet metal jobs and patterns are: the scratch awl, flat steel square, circumference rule, straightedge, dividers, trammel points, prick punch, and the center punch. When you are making your practice layouts you will in all probability be restricted in the use of sheet metal. If at all possible, use a "template paper." This material has a waxed surface that is well adapted to scribe and divider marks. If this type of paper is not available, use heavy brown wrapping paper, or discarded chart paper which can be obtained from the navigator or quartermaster. When you use paper, it will be necessary for you to substitute a 4H pencil for the scribe, and a pencil divider for your regular layout dividers. You'll have to take good care of your scribes, pencils, dividers, and rules, because the accuracy of your work depends upon them. After you have made a few practice layouts, the importance of accurate measurements will be more firmly impressed in your mind. You will have a feeling of satisfaction when your layout "comes out" in the manner you planned. If it doesn't quite fit, the probability is that you were careless somewhere along the line.

USING LAYOUT TOOLS

Figure 217 illustrates the correct manner in which to scribe a line, using a scratch awl and rule. Hold the scale or straightedge firmly in place. Set the point of the scriber as close to the edge of the scale as possible by tilting the scriber outward. Exert pressure on the point and draw the line, tilting the tool slightly in the direction of movement. For short lines, use the steel scale as the guide. For longer lines, use a circumference rule, or a straightedge. When you have a line to draw between

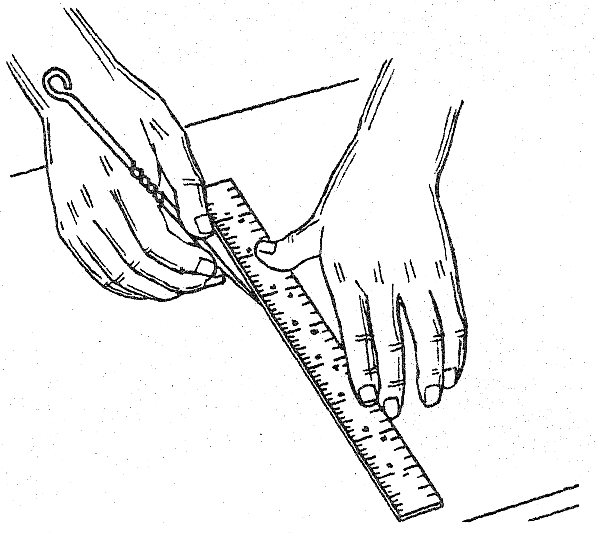


Figure 217.—Scribing a line.

two points, prick-punch each point. Start from one prick-punch mark and scribe toward the center. Complete the line by scribing from the other prick-punch mark in the opposite direction.

THE FLAT STEEL SQUARE is a useful tool for laying out sheet-

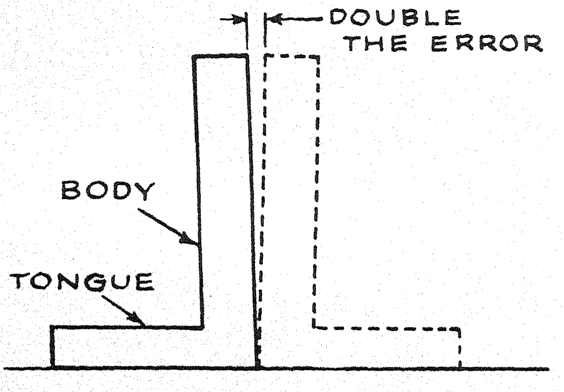


Figure 218.—Checking the square.

metal jobs. Before using it, or at least at periodic intervals, you should check the square for accuracy. When your square is off, your work will be proportionately off, no matter how careful you are. In parallel line developments, you will use the flat steel square to construct lines that are parallel to each other as well as perpendicular to the base line. This procedure is illustrated in figure 219. Just clamp the straightedge firmly to the base line. Slide the body of the square along the straightedge, and draw perpendicular lines through the desired points.

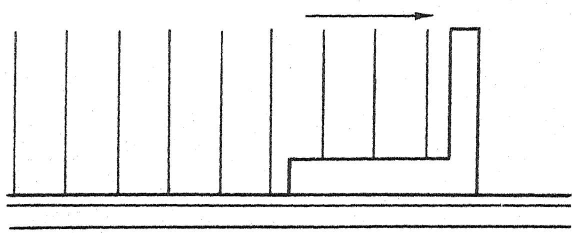


Figure 219.—Drawing perpendicular parallel lines.

THE COMBINATION SQUARE can be used to draw a similar set of lines as is illustrated in figure 220. An edge of the metal upon which you are working is used as the base line in both cases. One edge of the head of the combination square is 90° and the other edge is 45°.

Combination squares are delicate instruments and will be of little value to you if you permit them to receive rough handling. Stow your tools properly when you are not using them. Keep them clean and in tiptop shape, and you'll be able to construct 90° angles, 45° angles, and parallel lines, without error.

You have the tools to construct those angles without any strain. But how about lines at angles other than 45° or 90°? The PROTRACTOR is the tool you use for other angles. Mark the vertex of the angle on your base line with a prick punch (see figure 221). Set the vertex of your protractor on the mark, and then scribe a *V* at the desired angle (in this case 70°). Scribe the line between the vertex and the point located by the *V* and you have constructed an angle of 70°.

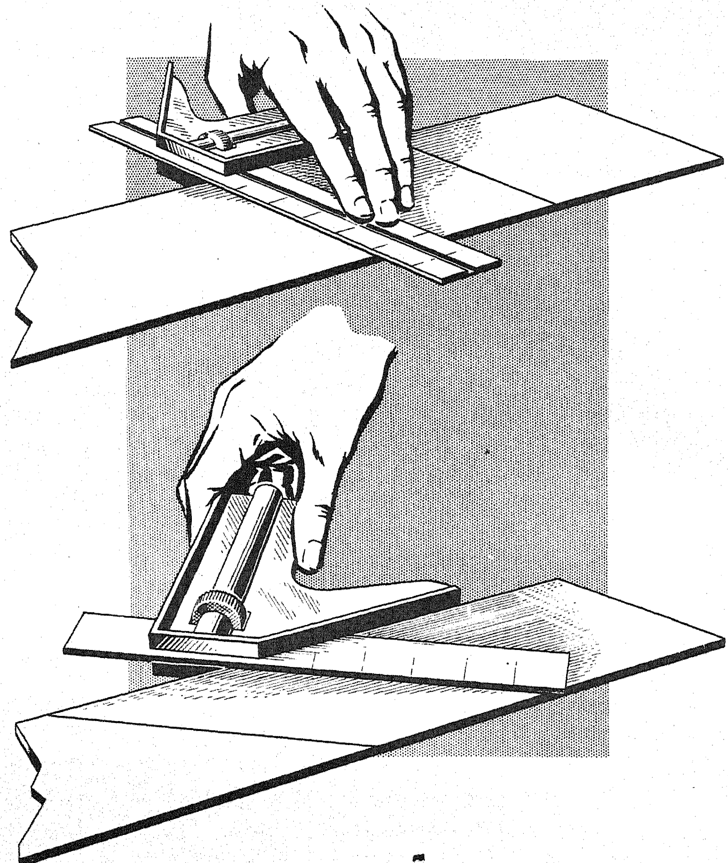


Figure 220.—Using combination square.

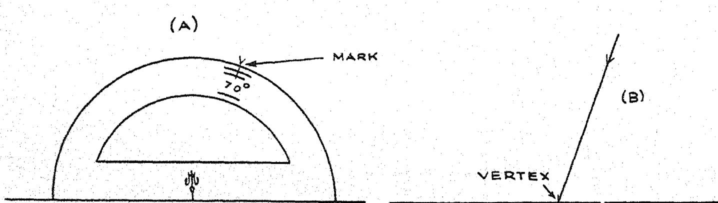


Figure 221.—Constructing an angle with the protractor.

When you locate a point and mark it with the PRICK PUNCH, be sure to use very light taps with a small ball-peen hammer. The smaller the mark you make (so long as you can see it), the more useful and accurate that mark becomes.

You will use DIVIDERS to scribe arcs and circles, to transfer measurements from a scale to your layout, and to transfer measurements from one part of the layout to another. Careful setting of the dividers is of prime importance. When you transfer a measurement from a scale to the work, set one point of your dividers on the mark and accurately adjust the other leg to the desired length as illustrated in figure 222.

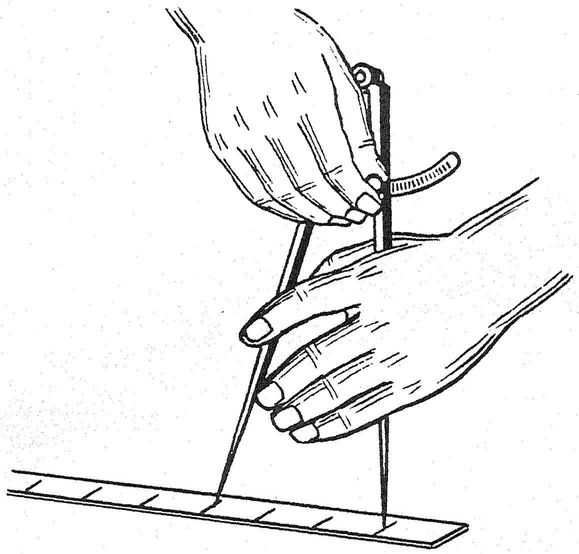


Figure 222.—Setting the dividers.

To scribe a circle, or an arc, grasp the dividers between the fingers and the thumb, place the point of one leg on the center, and swing the arc. Exert enough pressure to hold the point on center, slightly inclining the dividers in the direction in which they are being rotated (see figure 223).

There will be many times when you'll have to scribe a circle with a radius larger than your dividers. When you have that

problem, you will have to use TRAMMEL POINTS. The points are adjusted as illustrated in figure 224, by setting the left-hand point on one mark and sliding the right-hand point to the desired distance and tightening the thumbscrew. The arc, or circle, is then scribed in the same manner as with the dividers.

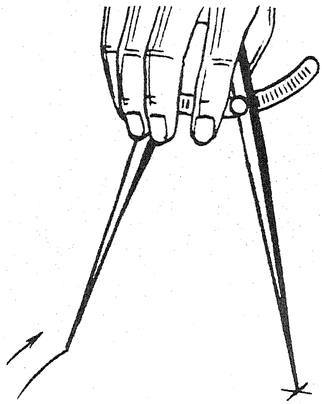


Figure 223.—Scribing an arc or a circle with dividers.

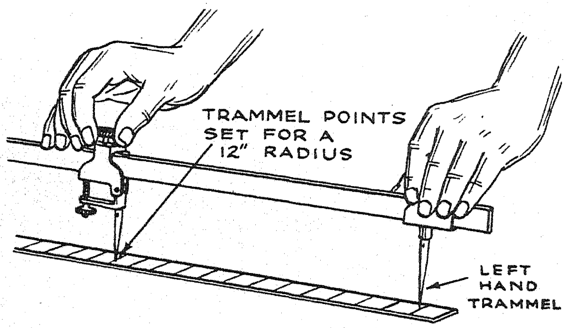


Figure 224.—Setting trammel points.

SIMPLE LAYOUTS

A STRETCHOUT is a pattern on a flat sheet which has not been formed. If a flat sheet is laid out to the correct shape and size, it may be formed into a three-dimensional object. Figure 225

shows three-dimensional objects being formed from flat patterns. When jobs are laid out, allowances for edges and seams must be added.

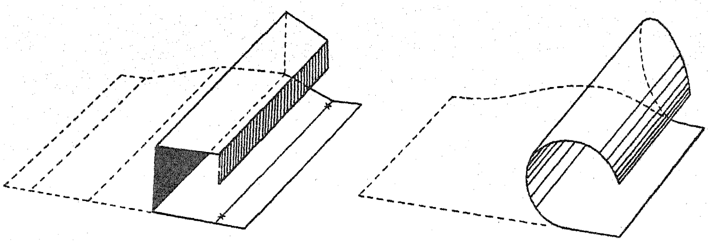


Figure 225.— Forming square and cylindrical shapes from flat patterns.

MAKING A DRIP PAN is a sheet metal job that you are sure to have as a striker in the sheet metal shop. Some of these pans, or boxes, will be used around the machinery in your shops. Take a look at them and see how they were made. Some have had the seams welded. Others are riveted and soldered. The welded seam is the fastest and easiest to lay out, but the riveted and soldered seam is by far the better of the two in sheet metal work. The various methods of seaming are discussed later in this chapter.

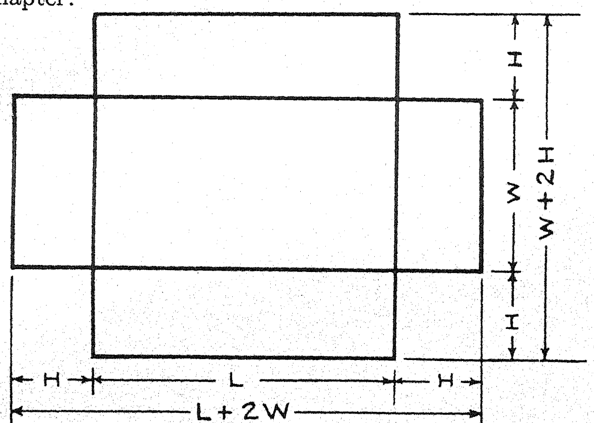


Figure 226.— Layout of a box or drip pan.

Break out your layout tools. Select a piece of sheet metal or template paper about one foot square. Lay out a pan, or box, similar to that shown in figure 226. Make the sides about 1½ inches in height, and the bottom about 9 inches square. Don't forget the tab for riveting. The angle on the tab is 45°. If this angle were not cut, you would have difficulty forming the side of the box. When you have the drip pan, or box, laid out, form the pan by breaking (bending) the sides up 90°. If you have made all of your measurements accurately, and have made your breaks on the line, the upper edge will be even all around, like the one shown in figure 227.

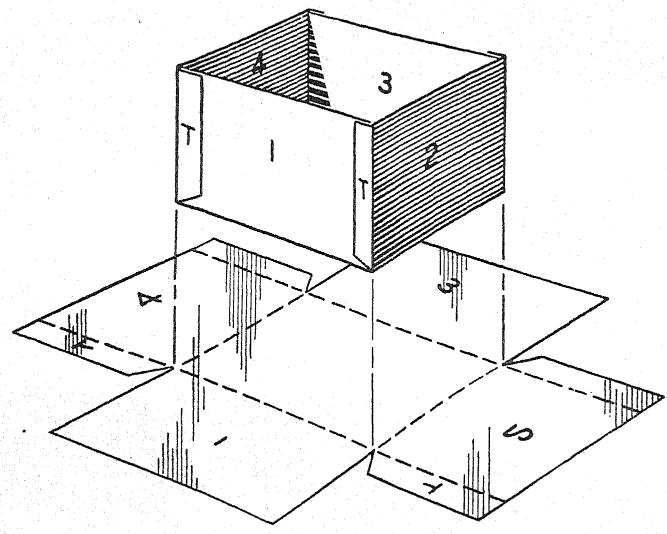


Figure 227.—Layout of box.

THE STRETCHOUT OF A CYLINDRICAL JOB will be rectangular in shape. One dimension of the rectangle will be the height of the cylinder, and the other dimension will be the circumference of the cylinder. When you're given measurements for a cylindrical job, however, you'll be given the diameter rather than the circumference of the cylinder. You'll have to find the circumference yourself.

The circumference may be determined by computation or with a circumference rule.

You remember the rule for finding the circumference of a circle from your *Mathematics*, NavPers 10620. Rule: The circumference of a circle is equal to 3.1416 times the diameter ($C = \pi D$). By the use of this formula you can find the length of the stretchout of any cylindrical object. Just multiply the diameter by 3.1416 (or you can use 3.14 or 3 1/7, depending on how accurate you wish to be), and the answer will give you one dimension for your stretchout. The length of the desired cylinder is your other dimension.

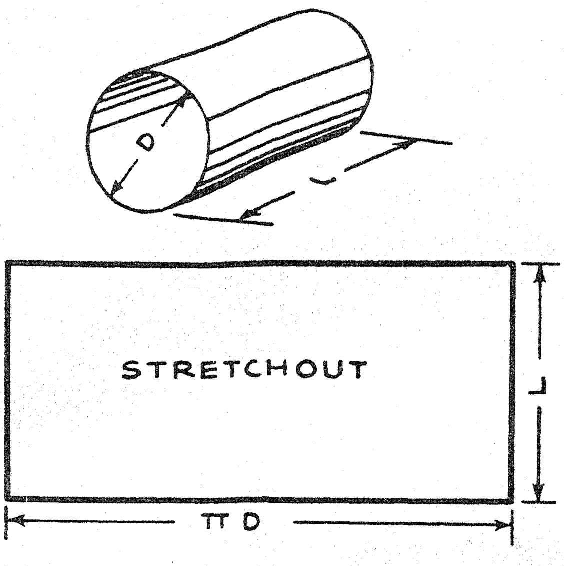


Figure 228.—Stretchout of a cylinder.

Another method is by the use of the circumference rule. The upper edge of the circumference rule is graduated in inches in the same manner as your regular layout scale, but the lower edge is graduated quite differently (see figure 229).

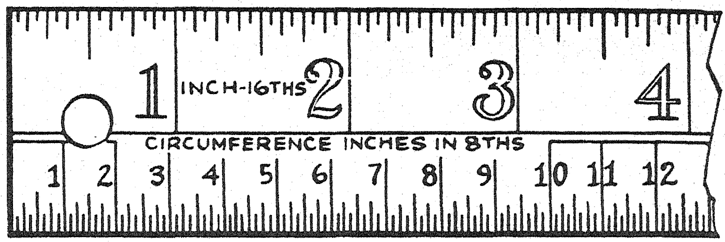


Figure 229.— Circumference rule.

The lower edge gives you the approximate circumference of any circle within the range of the rule. You will notice in figure 229 that the reading on the lower edge directly below the 3-inch mark is a little over 9⅜ inches. This reading would be the circumference of a circle with a diameter of 3 inches and would be the length of a stretchout for a cylinder of that diameter. The dimensions for the stretchout of a cylindrical object, then, are the height of the cylinder and the circumference. Don't forget that you'll have to allow for your seams.

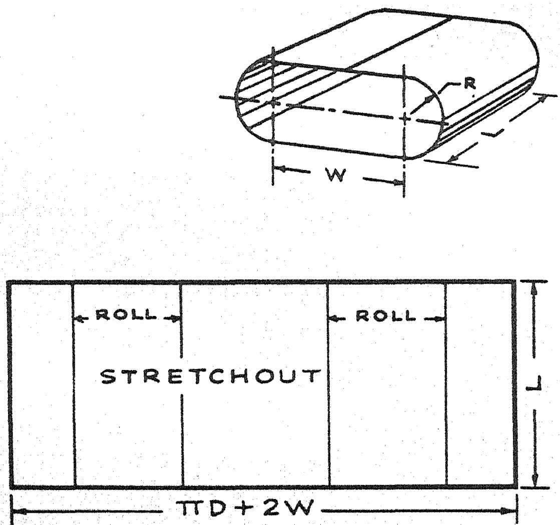


Figure 230.— Variation of cylinder.

A VARIATION OF THE CYLINDRICAL JOB that you'll run into is a flat-sided structure with rounded ends. Such a shape is shown in figure 230.

To figure the stretchout for this shape, find the circumference of a completed circle of the diameter of such a circle as would be formed by the two curved ends of the shape. Then add twice the length of the straight part—W in your illustration. Use the following equation for figuring your unknown dimensions $\pi D + 2W$. The symbol π is always 3.1416. Here is an example: let $D = 5$, and $W = 6$. Now, $3.1416 \times 5 + (2 \times 6) = 27.7080$, or about 27¾ inches. So one side of your stretchout will be 27¾ inches, and the other will be the length of the shape that you are making.

SUBSTITUTING KNOW HOW FOR TOOLS

CONSTRUCTING A 90° OR RIGHT ANGLE is no trick at all if you have a true steel square. But suppose that you have no square, or that you have a square which is off. You still need a right angle for your layout. Break out your dividers, a scriber, and a straight edge. Draw a base line like the one labeled *AB* in figure 231. Set your dividers for a distance greater than one-

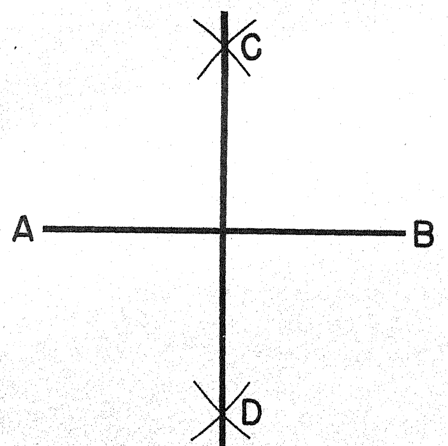


Figure 231.—Constructing a 90° angle by bisecting a line.

half AB, then, with A as a center, scribe arcs like those labeled C and D. Then, without changing the setting of your dividers, use B as a center, and scribe another set of arcs at C and D. Draw a line through the points where the arcs intersect and you will have erected perpendiculars to line AB, forming four 90° or right angles. You will also have bisected, or divided line AB into two equal parts.

CONSTRUCTING A RIGHT ANGLE AT A GIVEN POINT with a pair of dividers is a trick that you'll find quite useful in making layouts. Figure 232 is an illustration of a method for constructing a right angle at a given point.

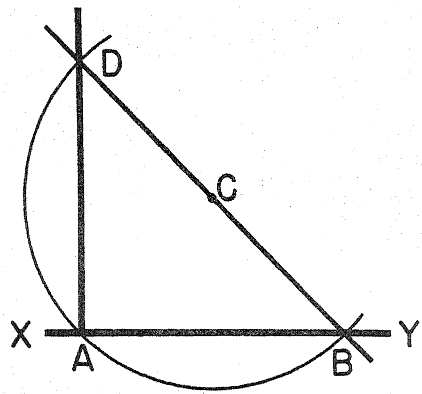


Figure 232.— Constructing a 90° angle at a given point.

Suppose that you have line XY with A as a point at which you need to erect a perpendicular to form a right angle. Select a point within the proposed angle that you wish to construct. In figure 232 that point is C. Set your dividers equal to CA, and using that distance for a radius, swing an arc BAD with C as a center. Lay a straightedge along the points B and C and draw a line which will intersect the other end of the arc at D. Now, draw a line connecting the points D and A and you have constructed a 90° angle. This method may be used to form 90° corners in stretchouts that are square or rectangular, like a drip pan or a box.

LAYING OUT A DRIP PAN WITH A PAIR OF DIVIDERS is no more difficult than erecting a perpendicular. You'll need dividers, scribe, straightedge, and a sheet of template paper. You know your dimensions, the length, width, and height or depth to which the pan must be made. Draw a base line (see figure 233). Select a point on this line for one corner of your drip-pan layout. Erect a perpendicular through this point forming a 90° angle.

Now, measure off on the base line the required length of the pan. At this point erect another perpendicular. You now have three sides of your stretchout. Using the required length of the pan for the other dimensions, draw the fourth side parallel to the base line, connecting the two perpendiculars that you have erected.

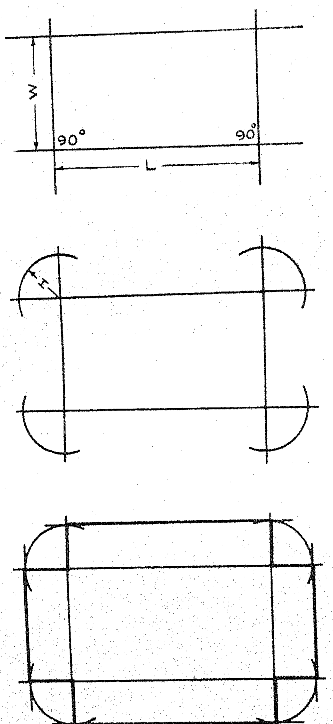


Figure 233.—Laying out a drip pan with dividers.

Now, set your dividers for marking off the depth of the drip pan. You can use your steel scale to measure off the correct radius on the dividers. Using each corner for a point, swing a wide arc like the one shown in the second illustration in figure 233. Extend the end and side lines as shown in the last illustration in figure 233, and complete the stretchout by connecting the arcs with your scribe and straightedge. The next step is to lay out your tabs like those shown in figure 227. Their size is determined by the diameter of the rivet, which in turn is determined by the thickness of the sheet. All that remains to be done now is to transfer the pattern to your sheet, cut the metal, and form it.

You have seen how a pan can be laid out without the use of a steel square by the use of geometric constructions. You bisected a line, erected a perpendicular from a given point on a line, and drew parallel lines by geometric construction. You'll find that these and other geometrical principles may be used to do a lot of layout problems rapidly and accurately.

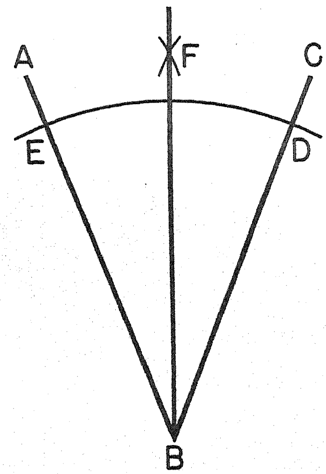


Figure 234.—Bisecting an angle.

BISECTING AN ARC is another geometric construction with which you should be familiar. Angle ABC (see figure 234) is given. With B as a center, draw an arc cutting the sides of the angle at D and E. With D and E as centers, and with a radius greater than half of arc DE, draw arcs intersecting at F. A line drawn from B through the point F bisects the angle ABC.

TO DIVIDE A LINE INTO A GIVEN NUMBER OF EQUAL PARTS, you need only a straightedge and a protractor. Figure 235 illustrates the simplicity of the geometric method. AB is the given line

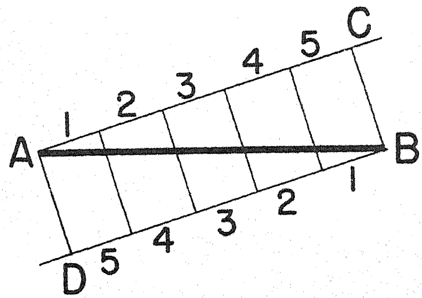


Figure 235.—Dividing a line into equal parts.

which is to be divided into five equal parts. From point A draw line AC at any convenient angle, and to a length that is readily divisible into five equal parts. From line B draw line BD so that the angle ABD is equal to CAB. Point off on BD the same number and size units as those pointed off on line AC. Connect the corresponding points on AC and BD. The connecting lines then divide line AB into five equal parts.

TO DIVIDE OR STEP OFF THE CIRCUMFERENCE OF A CIRCLE into six approximately equal parts, just set your dividers for the radius of the circle and select a point on the circumference for a beginning point. In figure 236, point A is selected for a beginning point. Swing an arc through the circumference of the circle like the one shown as B in the illustration. Use B, then, as a point, and swing an arc through the circumference at C. Continue to step off in this manner until you have divided the circle into six equal parts. If the points of intersection between

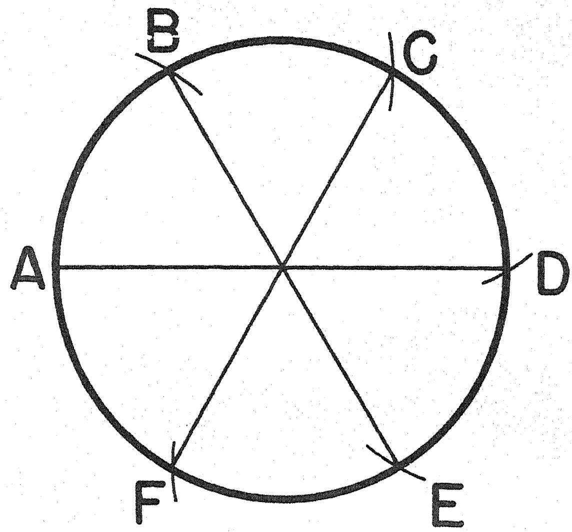


Figure 236.— Dividing a circle into six equal parts.

the arcs and the circumference are connected as shown in the illustration, the lines will intersect at the center of the circle, forming angles of 60°.

If you need an angle of 30°, all you have to do is to bisect one of these 60° angles, by the method described earlier in this chapter. Bisect the 30° and you have a 15° angle. You can construct a 45° angle in the same manner by bisecting a 90° angle. In all probability, you'll have a protractor to lay out these and other angles. But just in case you don't happen to have a steel square or protractor, it's a good idea to know how to construct angles of various sizes and to erect perpendiculars.

LAYING OUT A SQUARE OR RECTANGULAR ELBOW WITH A PAIR OF DIVIDERS is another job in which you will use geometric construction. Take a look at figure 237. *A* in the illustration shows you what the completed job should look like. Now, to make your layout for this job, draw the base line *OZ* shown in *B* in the illustration. Set your dividers for a distance equal to the width of the cheek. This distance forms the throat radius.

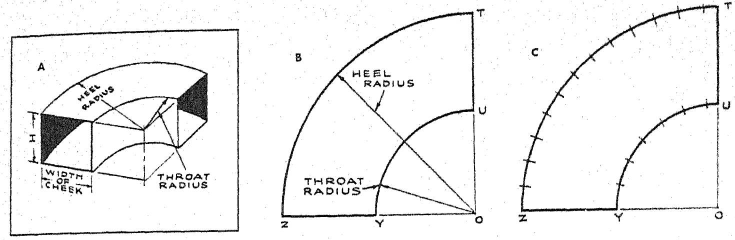


Figure 237.—Layout of square or rectangular elbow.

This rule will not always apply, as it must often be governed by the amount of space available to make the turn with the elbow. Now, with O as a center, scribe the arc YU. To get the heel radius, add the width of the cheek to the throat radius. Using O as a center, scribe the arc ZT. These layouts, when cut, will form the cheeks, or sides, of the elbow. The next operation is to lay out the heel and throat pieces. These are the other two of the four sides of your elbow, the throat being the inside piece, and the heel the outside piece. Set the dividers at exactly one inch, and step off the heel and throat arcs as shown in C, figure 237. If there is a distance of less than one inch left at the end of the arc, measure it with another pair of dividers or a scale. To make the stretchout of the heel and throat, lay out one piece of metal equal to the height of the elbow (see A in figure 237), and equal in length to the number of steps taken with the dividers, plus the fraction of an inch left over. One stretchout will be the heel and the other the throat. You can assemble this elbow by the fusion welding process, in which case you won't need to allow for tabs. But welding will cause a thin section to warp, so you may need to use some of the other standard methods for joining this type of work.

WORKING FROM PLANS

When you became a striker for Metalsmith, you probably spent your first day in the shop just looking around. You watched the men in the shop do the many varied jobs. Did you notice that all of the men in the shop who were laying out work were doing so from some sort of plan? This plan may have been

a sketch, a drawing, or a blueprint. In order for you to lay out work, you will have to be able to read these plans, and as you climb the ladder of advancement you'll be expected to make sketches and drawings.

A SKETCH is a rough outline of the structure to be fabricated, giving dimensions and details of the job to be done. Such information as angles to be used, and type of material required are included in the sketch.

A DRAWING is similar to a sketch, but it is made with mechanical drawing instruments and it is drawn to scale.

A BLUEPRINT is a duplicate of a drawing or sketch. Usually, only accurate drawings are blueprinted. These blueprints are furnished by the manufacturers of the machinery installed aboard your ship, and also by the bureaus concerned with the building and maintenance of the ship on which you are serving.

Your ability to read blueprints, drawings, and sketches is of prime importance to you, since your ability to interpret information of this sort will determine your importance to your section and your ship. Study your basic training course, *Use of Blueprints*, NavPers 10621. You'll find that this book will help you to read almost any kind of plan that you'll run into. A satisfactorily completed job is your objective or destination, and the plans from which you work are the road maps to your destination. Be able to read them accurately.

DON'T FORGET THE EDGES

Thus far your practice jobs have been laid out to be formed with the edges left as they are. Very few of your jobs in the shop will actually be fabricated in this manner. Edges are formed to improve the appearance of the work, strengthen the piece, or to eliminate the raw edge. These edges may be formed from the metal itself by inserting wire, or by attaching a band or angle iron. The kind of edge that you will use on any job will be determined by the purpose, size, or strength of the edge needed.

THE SINGLE-HEM EDGE is illustrated in figure 238. This edge can be made in any width. In general, the heavier the metal, the

wider the hem is made. The allowance for the hem is equal to its width (*W* in figure 238).

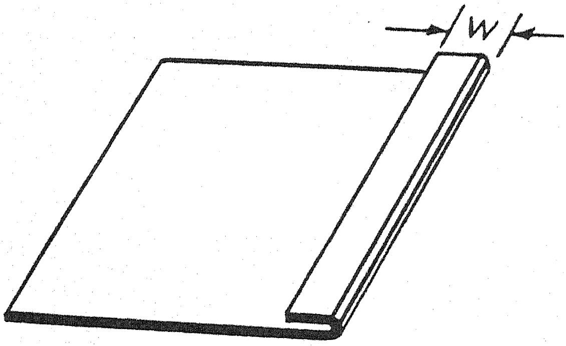


Figure 238.— Single-hem edge.

THE DOUBLE-HEM EDGE (figure 239) is used where additional strength is needed, or when a smooth edge is desired inside, as well as outside. The allowance for the double-hem edge is twice the width of the hem.

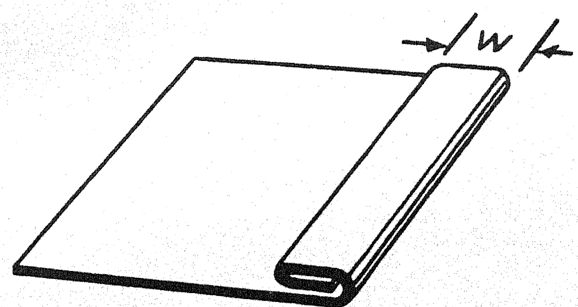


Figure 239.— Double-hem edge.

A WIRED EDGE (figure 240) will often be specified in your plans. Objects such as ice-cube trays, funnels, garbage pails,

and other articles formed from sheet metal are manufactured with wired edges to strengthen and stiffen jobs and eliminate sharp edges. The allowance for a wired edge is 2½ times the diameter of the wire used. For example, if you are using wire which has a diameter of ⅛ inch, multiply ⅛ by 2½ and your answer will be 5/16 inch, which you will allow when laying out your sheet metal for making the wired edge.

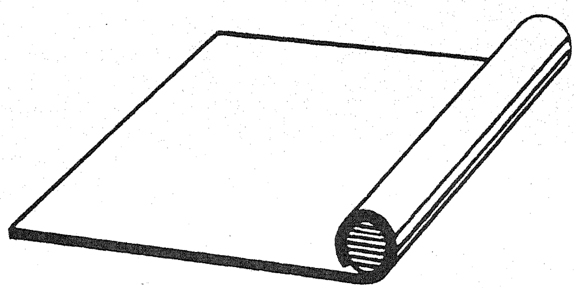


Figure 240. — Wired edge.

SHEET METAL SEAMS

When you made your layout for a drip pan or box, you were instructed to allow for a tab for seaming with rivets. This method of joining sheet metal is known as lap seaming.

Lap seams may be of three kinds: the plain lap seam, the offset or "joggled" lap seam, and the corner lap seam. Lap

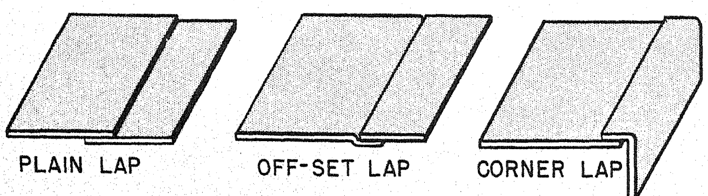


Figure 241. — Lap seams.

seams may be joined by drilling and riveting, by soldering, or by a combination of both riveting and soldering. To figure your allowance for a lap seam, you must first know the diameter of the rivet that you plan to use. The center of your rivet must be set in from the edge a distance of two times its diameter. Your allowance, then, must be four times the diameter of the rivet that you are to use. Figure 242 illustrates the manner in which a plain lap and a corner lap are laid out for seaming with rivets (*d* represents the diameter of the rivets). For corner seams, allow an additional 1/16 inch for clearance.

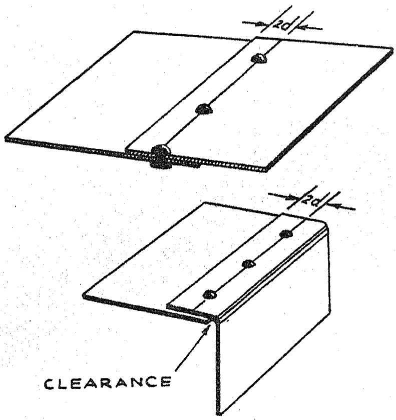


Figure 242.—Layout of lap seams for riveting.

GROOVED SEAMS are useful in the construction of cylindrical shapes. There are two types of grooved seams—the outside grooved seam, and the inside grooved seam (see figure 243). The allowance for a grooved seam is three times the width (*W* in figure 243) of the lock, one-half of this amount being added to each edge. For example, if you are to have a 1/4 inch grooved seam, 3x1/4 = 3/4 inch, or the total allowance; 1/2 of 3/4 inch = 3/8 inch, or the allowance that you are to add to each edge.

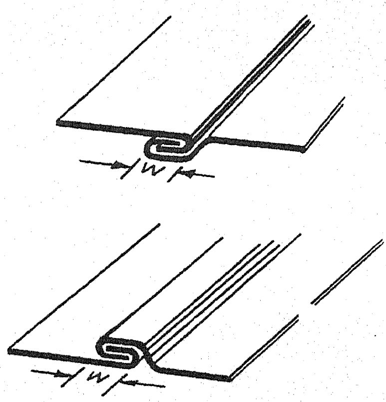


Figure 243. — Grooved seams.

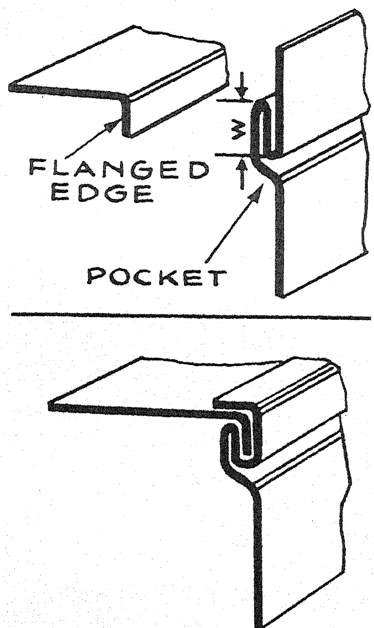


Figure 244. — Pittsburgh lock seams.

The Pittsburgh lock seam is a very useful corner seam which is used to advantage in the fabrication of rectangular ventilation lines, elbows, and boxes. At first glance, the seam appears to be quite complicated, but like lap and grooved seams it consists of only two pieces. The two parts are the flanged or single edge, and the pocket that forms the lock. The pocket is formed, the flanged edge is inserted into the pocket, and the projected edge is turned over the inserted edge to form the lock.

The allowance for the pocket is: $W + W + \frac{3}{16}$ inch. W is the width or depth of the pocket. The width of the flanged edge must be less than W. For example, if you are laying out a $\frac{1}{4}$ inch Pittsburgh lock, your total allowance should be $\frac{1}{4} + \frac{1}{4} + \frac{3}{16}$ inch, or $\frac{11}{16}$ inch for the edge on which you are laying out the pocket, and $\frac{3}{16}$ inch on the flanged edge.

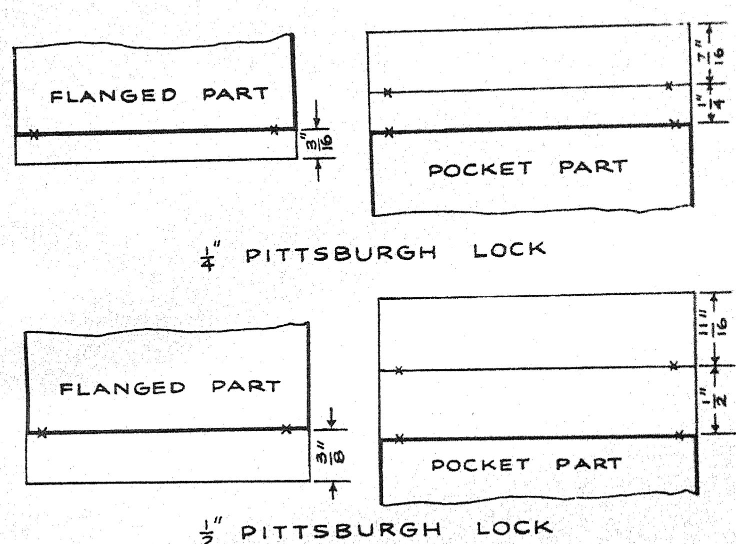


Figure 245.—Layout of Pittsburgh lock seams.

LAYING OUT NOTCHES

Notching is the last but not the least important step to be considered when you are getting ready to lay out a job. Before you can mark a notch, you'll have to lay out the pattern and

add the seams, laps, or stiffening edges. If the patterns aren't properly notched, you'll have trouble when you start forming, assembling, or finishing the job.

No definite rule for selecting the proper notch for the job can be given. But as soon as you get to where you can visualize the assembly of the job, you won't have any trouble determining the shape of the appropriate notch for the job. If the notch is made too large, a hole will be left in the finished job. If the notch is too small, or not of the proper shape, the metal will overlap and bulge at the seam or edge. Don't worry too much if your first notches don't come out too well—practice and experience will take care of that.

A SQUARE NOTCH is probably the first you'll make. That's the kind you were instructed to make in your practice layout of a box or drip pan. Take a look around the shop to see just how many different kinds of notches you can see in the sheet metal shapes. The metal frame in which the Battle Bill is posted is probably made with a slant notch.

SLANT NOTCHES are cut at a 45° angle across the corner, when a single hem is to meet at a 90° angle. Figure 246 illustrates the steps in forming a slant notch.

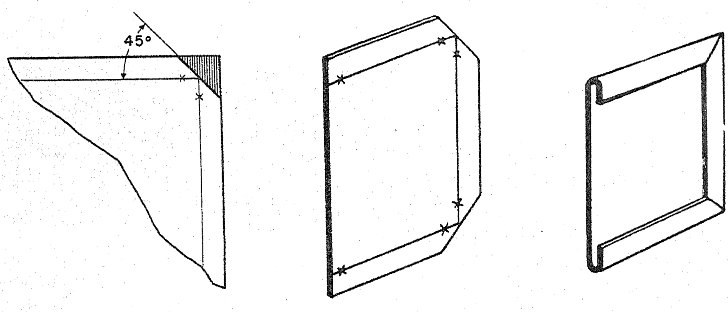


Figure 246.—Slant notch.

A *V*-NOTCH is used for seaming ends of boxes. You'll also use a full V-notch when you have to construct a bracket with a toed-in flange or for similar construction. The full V is illustrated in figure 247.

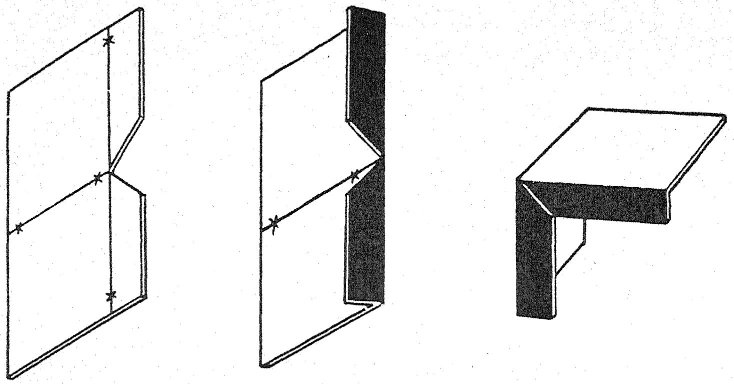


Figure 247.—V-notch.

When you are making an inside flange on an angle of less than 90°, you'll have to use a modification of the full *V*-notch to get flush joints. The angle of the notch will depend upon the bend angle. A modified *V*-notch is shown in figure 248.

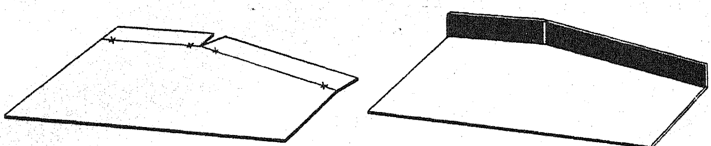


Figure 248. — Modified V-Notch.

A WIRE NOTCH is a notch used with a wired edge. Its depth from the edge of the pattern will be one wire's diameter more than the depth of the allowance for the wired edge ($2\frac{1}{2}d$), or in other words, 3 ½ times the diameter of the wire ($3\frac{1}{2}d$). Its width is equal to 1½ times the width of the seam ($1\frac{1}{2}w$.) That portion of the notch next to the wired edge will be straight. The shape of the notch on the seam will depend upon the type of seam used, which, in figure 249, is 45° for a grooved seam.

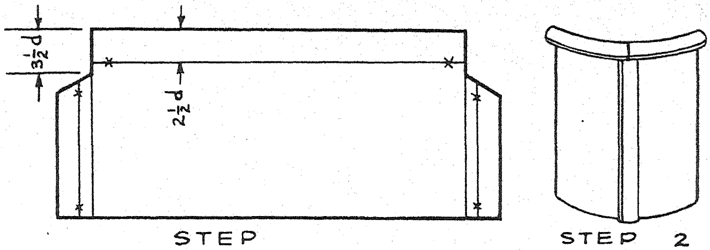


Figure 249. — Wire notch in cylindrical layout.

Most of your work will require more than one type of notch just as shown in figure 249, where a wire notch was used in the forming of a cylindrical shape joined by a grooved seam. In such a layout, you'll have to notch for the wired edge and the seam.

Another combination of notches that you'll be running into is in laying out and making an ice-cube tray. The tray itself is similar to the drip pan you have laid out, but the upper edge will require a wired edge. In this job, you'll have to use the wire notch, the modified *V*, and the square notch (see figure 250).

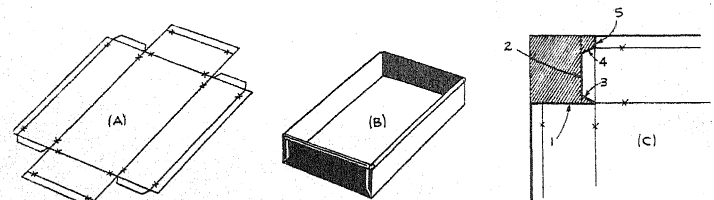


Figure 250. — Notching for an ice-cube tray.

DEVELOPING PATTERNS

If all the work that you were called upon to perform consisted of laying out and fabricating drip pans, boxes, lockers, and straight sections of cylindrical and rectangular ventilation lines, your work would be much easier. Your layout work would consist of nothing more than straight-line angular development, plus allowances for seams and edges, and visualizing the notch needed. But you'll have to construct ventilation systems, or

at least make repairs to those systems. This work calls for elbows and tees which can't be laid out unless you know parallel line development.

PARALLEL-LINE DEVELOPMENT is based upon the fact that a line which is parallel to another line is an equal distance from that line at all points. The main lines of a structure to be laid out by parallel-line development are parallel to each other. Objects which have opposite lines parallel to each other, or which have the same cross-sectional shape throughout their length, are developed by this method. This includes such shapes as the cylinder and prism and their many variations.

You'll have to observe certain fixed principles as follows:

1. A plan and an elevation of the desired shape must first be drawn in which the parallel lines of the solid are shown in their true lengths.
2. Visualize the pattern from a right view of the article in which the miter lines or lines of intersection are shown.
3. Draw a stretchout or girth line at right angles to the parallel lines of the solid, upon which is placed each space contained in the section or plan view.
4. Draw measuring lines at right angles to the stretchout lines of the pattern.
5. Draw lines from points of intersection of the miter line, in the right view, intersecting similarly numbered measuring lines drawn from the stretchout, to show the outline of the development.
6. Trace a line through the points thus obtained to give the desired pattern.

Now, let us develop, step by step, a layout of an intersected pipe by the parallel-line method. Such a pipe might be used for a ventilation pipe on a slanting roof. Follow through on the instructions, checking each step with the illustration shown in figure 251. Then break out your layout tools and a sheet of template paper and try one for yourself.

First, construct an elevation on the miter line similar to the one shown in figure 251. The miter line is the inclined plane or slanting roof. The elevation is a front view. Line AB represents

the diameter of the pipe. The distance between line AB and the miter line is the height of the pipe, which will vary around the circumference of the pipe.

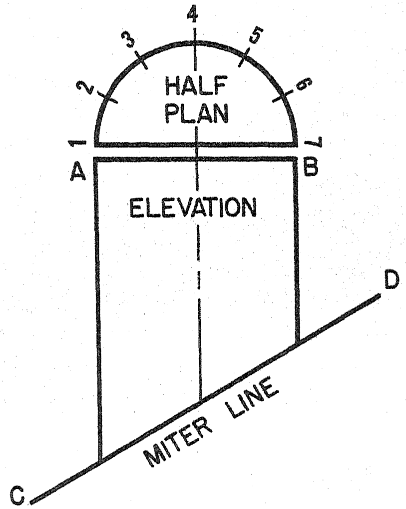


Figure 251.—Elevation and plan of intesected pipe.

Now, determine the center of line AB, and construct a center line as shown in figure 251. Set your dividers for one-half the distance of line AB. Develop your plan by the following steps:

1. Construct line 1-7 parallel to and just above AB. Using the point at which the center line of the elevation intersects line 1-7, swing an arc with your dividers and complete the half plan as shown.
2. Step off the circumference of the half plan with your dividers into six equal parts.
3. Set your straightedge at right angles to the center line, and using it as a base line, draw lines parallel to the center line by the method illustrated earlier in figure 219. The parallel lines must be drawn from the points where the arcs intersect the circumference of the half plan to the miter line (see figure 252).

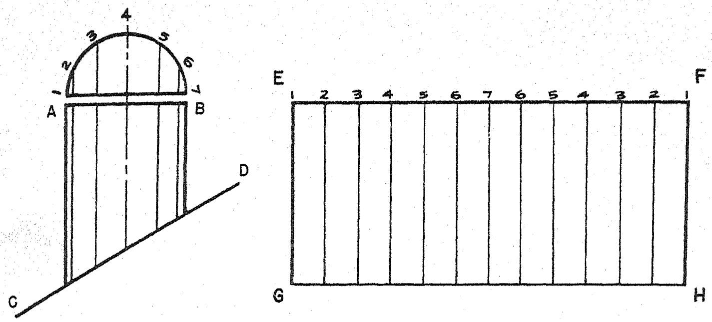


Figure 252.— Development of layout for intersected pipe.

4. With your straightedge draw EF, (an extension of line AB), and step off twice the distance you stepped off in the circumference of the half plan.
5. Draw a line GH parallel to EF at a distance equal to the greatest height of the elevation.
6. Through the points located on the extended line, by stepping off with your dividers, draw parallel lines at right angles to the line extended from AB.
7. Number these lines in the proper order as illustrated (1 to 7 to 1).

You are all set now to transfer the miter line CD in the elevation to the stretchout. To transfer the miter line to the stretchout and thus form the stretchout for the elevation, you may use either of two methods:

1. By measuring, and transferring that measurement from the elevation to the stretchout, with the use of your dividers.
2. By projecting the points in the elevation to the stretchout by parallel projection lines (broken lines).

Whichever method you use, you'll come out with the same stretchout, if you are careful in your measurements. Try both methods and make a habit of using the one which comes easiest to you. To develop your pattern by use of the dividers, follow these step-by-step instructions, working from figure 252:

1. Set your dividers along line 1 to equal the distance from line *AB* to line *CD*.
2. Keeping your dividers set at this distance, transfer this measurement to the two lines numbered 1 in the stretchout. Using the points at which the lines marked 1 intersect the extension of *AB* as a point, scribe an arc cutting each of the lines equidistant to line 1 in the elevation.
3. Then, measure line 2 in the elevation, and transfer this measurement to the two lines marked 2 in the stretchout. Repeat this procedure for lines 3, 4, 5, and 6.
4. Notice that there is but one line 7 in your stretchout, so you will need to transfer the measurement of line 7 in the elevation to but one line 7 in the stretchout.
5. Finally, connect the points at which the arcs have intersected each of the elements, with a curve running from line 1 to the opposite line 1. Smooth out your curved line, add your allowances for seams, and your pattern is complete. If this final line has serious irregularities, you have made a mistake in measurement. Your final stretchout will look exactly like the one made by projection in figure 253.

To obtain the pattern by projection, you merely project parallel broken lines from the points of intersection on the miter to like-numbered lines in the stretchout. These lines are drawn

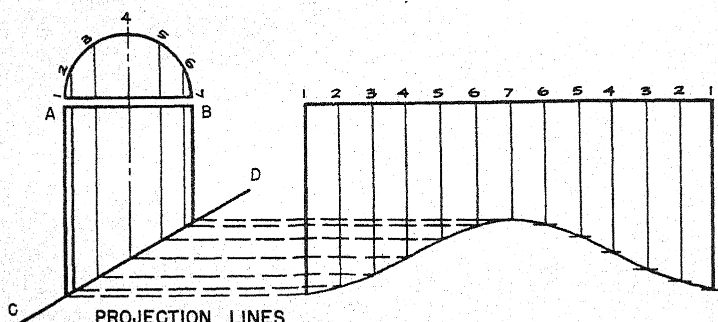


Figure 253.—Transferring from elevation to stretchout to make the pattern.

at right angles to the numbered lines and parallel to line AB. They are drawn from the point at which the numbered lines intersect the miter CD to the point at which they intersect the most distant like numbered line in the stretchout. Again, the pattern is completed by connecting the points of intersection on the stretchout with a curved line. Remember, the more care you take in drawing your elevation, stepping off the half plan, and transferring your measurements from the elevation to the stretchout, the more accurate your pattern will be. Figure 254 is a pictorial view of the plan you have just laid out.

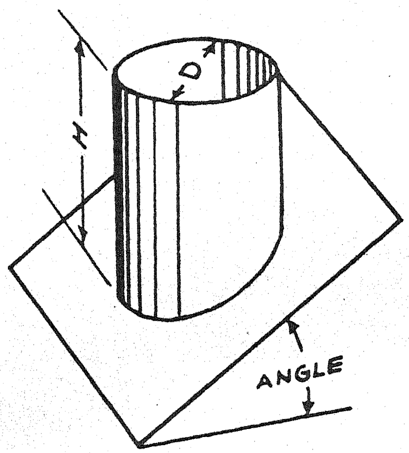


Figure 254.— Pictorial view of pipe intersected at an angle.

The parallel-line method can also be used to develop an elbow of any desired diameter, depth of throat, or number of pieces. Figure 255 illustrates the development of a five-piece 90° elbow. If you feel the need for a bit of brain calisthenics, "turn to" on this one with a pair of dividers and a straightedge.

1. Using figure 255 as a model, draw an angle similar to ABC.
2. Set your dividers for the throat radius, T in the illustration, and scribe the arc.

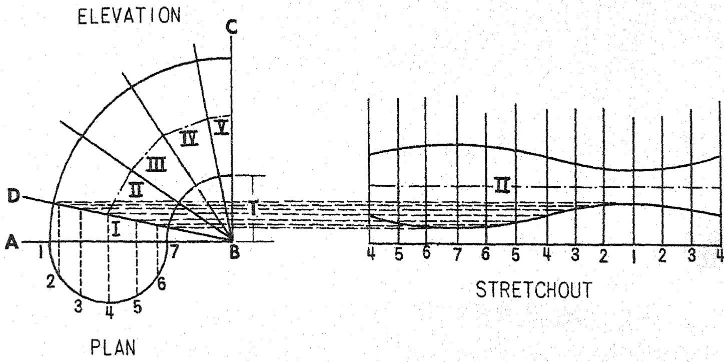


Figure 255.—Development of a five-piece 90° elbow.

3. Set your dividers for the heel radius and scribe the heel arc. (The heel radius is determined by adding the diameter of the elbow to the throat radius.)

4. Step off the heel arc *AC* with your dividers into equal spaces. (To determine the number of spaces to use, follow this rule: Multiply the number of pieces in the elbow by 2 and subtract 2. In other words—number of pieces x 2 − 2 = number of equal spaces to use when dividing the heel arc. For a five-piece elbow—5 x 2 − 2 = 8.)

5. Now, draw lines from the vertex *B* to the points stepped off on the heel arc, making piece I and V equal to one space each on the heel arc. Pieces II, III, and IV are made equal to two spaces each on the heel arc. They are twice the size of I and V.

6. Using *AB* for the base line, construct the half plan.

7. Step off the circumference of the half plan into equal spaces, and number the dividing lines from 1 to 7. For a larger diameter, use a greater number of equal spaces. The greater number of spaces you use, the more accurate your plan will be.

8. Use *BD* for the miter line. You have now completed your

elevation for making the stretchout of piece II, which will be the same for III and IV, and for making stretchout of piece I which will be the same as V.

9. Extend line AB to the right of the elevation to make the stretchout.

10. Set your dividers equal to one of the numbered divisions in the half plan.

11. Step off twice the number of equal spaces in the stretchout that you have in the half plan.

12. Erect perpendiculars from the base line of the stretchout and number them as shown in figure 255. (The number with which you begin and end in your stretchout will determine the location of the seam in your finished elbow. The best location for a seam on an elbow is on the side, so you number from 4 to 7 to 1 to 4. Numbering from 1 to 7 to 1, as was shown in the previous development, would place the seam on the heel. This is not desirable as it would take more time and material to complete the seam. Numbering from 7 to 1 to 7 would place the seam in the throat of the elbow, and that too, would be undesirable, since often the space available for seaming the throat is too little to make a strong seam. The location of the seam is a matter of preference and is determined by the job you are laying out.)

13. To transfer the pattern from the elevation to the stretchout by the use of your dividers proceed as follows:
    (a) Set your dividers along line 4 in the elevation a distance equal to that from AB to BD.
    (b) Using this distance on your dividers, step off three spaces on each of the three lines 4 in the stretchout, starting from the base line of the stretchout.
    (c) The point on each of the lines 4 dividing the second and third space forms the center of your stretchout. Draw a line connecting these three points to form the center line of your stretchout.

(*d*) Now, using the point at which the center line and the numbered lines (elements) in the stretchout intersect, scribe arcs cutting each of the lines in turn the same length as are the corresponding lines in the elevation between base line *AB* and miter line *BD*.

(*e*) Connect these points with smooth lines which will be curved, and your stretchout is formed. Piece I in the stretchout (the lower piece) is the pattern for pieces I and V in the elbow, and piece II in the stretchout is the pattern for pieces II, III, and IV.

Figure 256 is a pictorial view of a five-piece elbow such as the one you have just laid out.

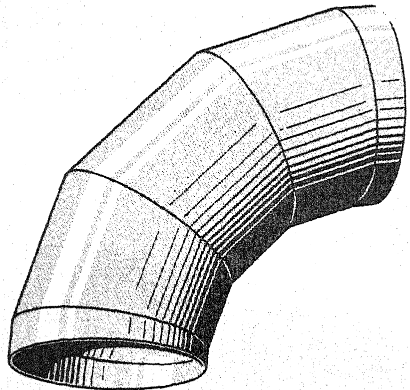


Figure 256.— Pictorial view of a five-piece elbow.

You have seen that to develop the stretchout, you must draw an elevation and a plan view. In the case of the intersected pipe and the elbow, it was necessary to draw only the one elevation and plan view. Some developments will require two or more elevations. An example of this type of development is the *T*-joint. To develop the *T*-joint it will be necessary for you to draw a side elevation and an end elevation as well as plan views. For the side elevation, you draw the object exactly as you would see it, looking directly at the side of the *T*. Now, imagine

that you are holding the *T* in the palm of your hand looking at the side. Revolve it toward you 90° so that you will be looking into the end of the main pipe and draw the end elevation (see figure 257).

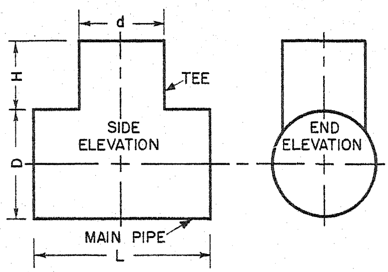


Figure 257.—Side and end elevation of a T-joint.

To construct the side and end elevation:

1. Draw a horizontal center line.
2. Construct parallel lines, leaving sufficient space for the development of your side and end elevations, intersecting the horizontal center line. These lines will form center lines for the two elevations.
3. Draw the plan view above the constructed elevations (see figure 258).
4. Step off the circumference of the plan view into equal spaces with your dividers.

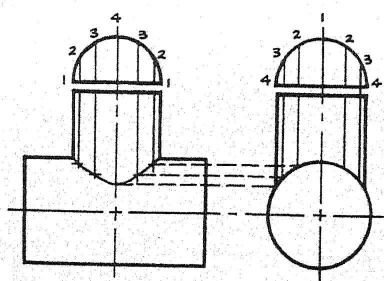


Figure 258.—Transferring elements to obtain miter line.

5. Number the elements of the plan as illustrated. The plan is numbered 1 to 4 to 1 because each quarter section of the intersection, or miter, of the two pieces is the same as any other quarter section in the elevation. If the intersection of the *T* were other than at a 90° angle, you would number from 1 to 7 as you did in developing the pattern for the elbow.

6. Extend lines parallel to the center lines in each of the views from the numbered points. In the end view these lines will be drawn to the main pipe. To determine the lower end of the lines in the side elevation, proceed as follows:

   (*a*) Place your straightedge at right angles to the number 4 vertical element of the end view. Draw a broken horizontal line from number 4 element of the end view to number 4 vertical element of the side view. Connect the other like numbered elements in the same manner. Remember that there are two elements numbered 3, 2, and 1 in the side elevation to be connected.

7. Draw a curve through the intersections you have just located on the side view.

8. To the right of the elevations, draw a stretchout equal in length to the circumference of the upper section of the *T* (see figure 259), or equal to twice the distance that you stepped off in the half plan. The height of the stretchout, obtained by projection, is equal to the maximum height of the *T*. The height is equal to the length of the longest element in the side elevation—in this case, element number 4.

9. Step off, locate, and number the element lines in the stretchout.

10. Project the points of intersection locating the miter in the side elevation. Draw the curve through these points.

11. Now, using the circumference and length of the main pipe for dimensions, draw the stretchout for the main pipe as shown in figure 260.

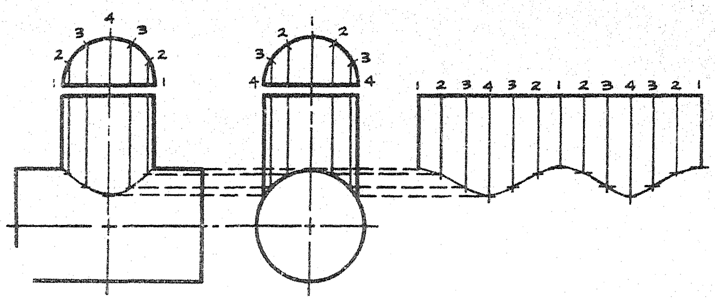


Figure 259. — Stretchout of the T.

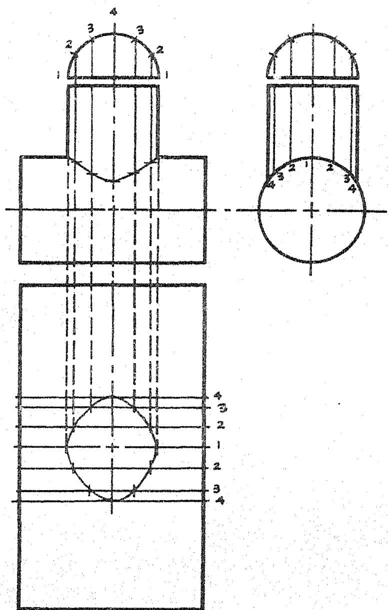


Figure 260. — Stretchout of the main pipe in the T-joint.

12. Bisect the length of the stretchout with an element line and number that line 1.

13. Set your dividers on the distance from 1 to 2 in the half plan in the elevation. Using this radius and the point at which line 1 intersects the right-hand edge of your stretchout, scribe an arc on either side of 1 on the edge of the stretchout. Number each of these points 2. Now, setting your dividers for the distance from 1 to 3 in the half plan of the elevation, scribe arcs using 1 as a center on either side of element 1 in the stretchout. Number these points both 3. Repeat the procedure to get the points for number 4 elements in the stretchout.
14. Through the points located, draw the element lines parallel to line 1.
15. Project the elements of the side elevation view to the correspondingly numbered elements in the stretchout. Connect the intersecting points with curved lines to outline the hole.
16. Add seams to the stretchout as required. Remember that the amount you will allow for seams will depend upon the method that you plan to use for joining.

When your layout is completed, transferred to sheet, and formed, you should have a shape like the one illustrated in figure 261.

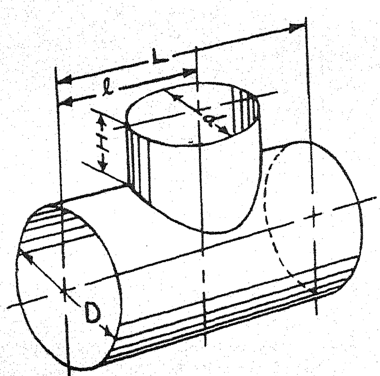


Figure 261.— Pictorial view of a T-joint.

You have seen that you can develop patterns for a drip pan or box by the straight line angular method of development, and you have been shown methods for making stretchouts for elbows, pipe intersection angles, and T's by the parallel line method. Each of these methods for the development of patterns has many more applications, and you'll use them often, but you won't be able to develop some of the patterns that you'll run into without a working knowledge of radial line pattern development.

THE RADIAL LINE METHOD of pattern development employs some of the features of parallel line development that you'll recognize when you have laid out a frustum of a right cone. You are familiar with the shape of a cone. A right cone is one which, if set big-side-down on a flat surface, would stand straight up. In other words, a center line drawn from the point, or vertex, to the base line, would form right angles with that line. The frustum of a cone is that part which remains after the point, or top, has been removed.

To develop a pattern for the frustum of a cone, check the following steps one by one with the illustration shown in figure 262.

1. Draw a side view of the cone, using such dimensions as your job at hand requires. Letter the vertex A and the base BC. At the point D, and parallel to line BC, draw a line that cuts the top from the bottom of the cone. The bottom portion is called the frustum.

2. Draw the half plan beneath the base of the frustum, step it off into an equal number of spaces, and number it as shown in the illustration.

3. Set your dividers the length of the cone along line AC, and using the vertex A for a center, scribe an arc equal to the length of the circumference of the bottom of the cone.

4. Set your dividers equal to the distance of the step-offs on your half plan, and step off twice as many spaces as you have in the half plan.

5. Number the step-offs from 1 to 7 to 1.

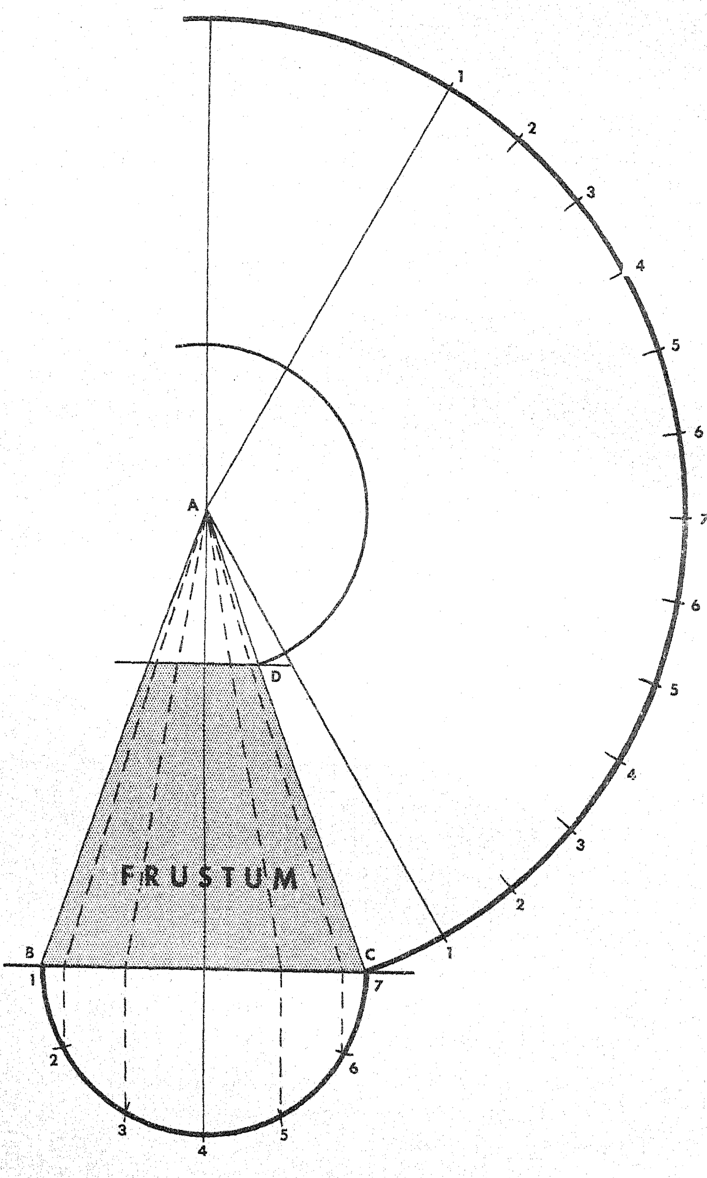


Figure 262.—Radial line development of frustum of right cone.

6. Draw lines connecting A with point 1 at each end of the stretchout.
7. Now, using A for a center, set your dividers along line AC to the length of AD. Scribe an arc through both of the lines drawn from A to 1.

The area enclosed between the large and small arcs and the number 1 lines is the pattern for the frustum of a cone. Add allowances for seaming and edging and your stretchout is complete.

To develop a pattern for a cone cut at any angle, you need merely to elaborate the development of the pattern for a frustum. Such a pattern is illustrated in figure 263.

To develop a pattern for a cone cut at any angle, follow the method given here step by step:

1. Draw a cone with a line such as DE cutting the cone.
2. Draw the half plan at the base of the cone, step off the equal spaces, and number them as you did in the pattern for a frustum for a right cone.
3. From the points on the half plan erect lines perpendicular to the base line BC. From the points at which these lines intersect BC, draw lines to the vertex A. Number the elements at the point of intersection on the angle line DE.
4. Set your dividers for a distance equal to AC, and with A as a center, scribe an arc for the stretchout of the bottom of the cone. Step off the distance of the circumference of the bottom of the cone on the stretchout.
5. From the step-off points on the arc, draw lines to the vertex. Number these elements in the same order as the half plan—7 to 1 to 7.
6. Using your dividers with A as a center, measure the length of line 7 in the elevation from A to line ED. Swing this arc still using A as a center to scribe arcs and locate points of intersection on each of the lines 7 in the stretchout. Repeat the procedure for each of the numbered lines.
7. Join these points of intersection with a curved line on the stretchout.
8. Add allowances for seaming and edging, and the pattern is complete.

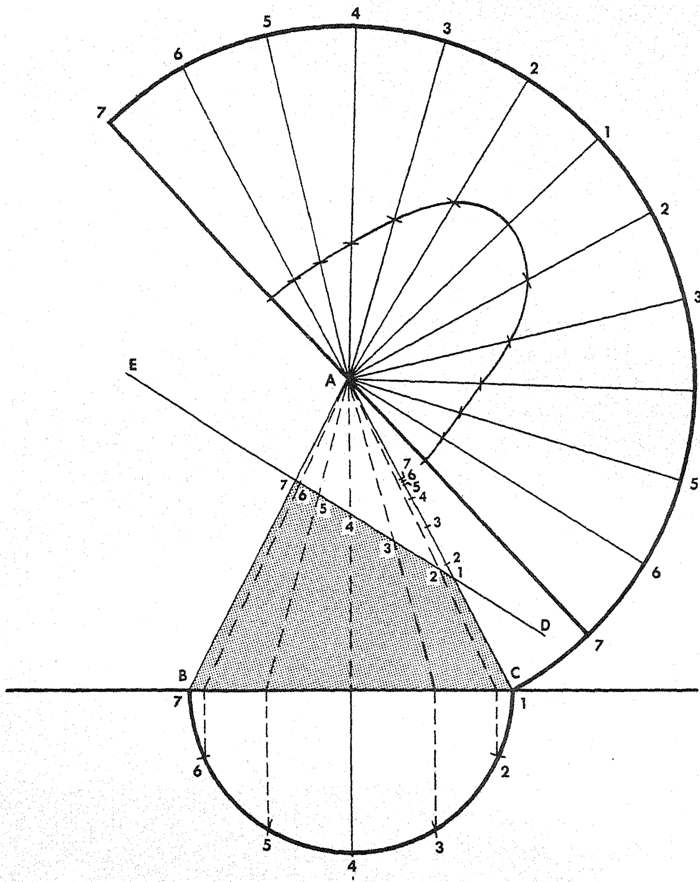


Figure 263. — Development of cone cut at any angle.

TRANSFERRING THE PATTERN TO METAL

Many of the patterns you make will be laid out right on the metal, but there will be times when you will have to make your development on paper and then transfer the pattern to the metal upon which you plan to work. When you transfer these measurements you must be careful to avoid mistakes or your piece will not "come out."

Occasionally, you may cut out the pattern from template paper. If this is the case, you will hold the pattern firmly in place and trace around the edges. The break lines (lines on which you'll bend the work) will be located by using a prick or center punch, and marking through the pattern on to the metal.

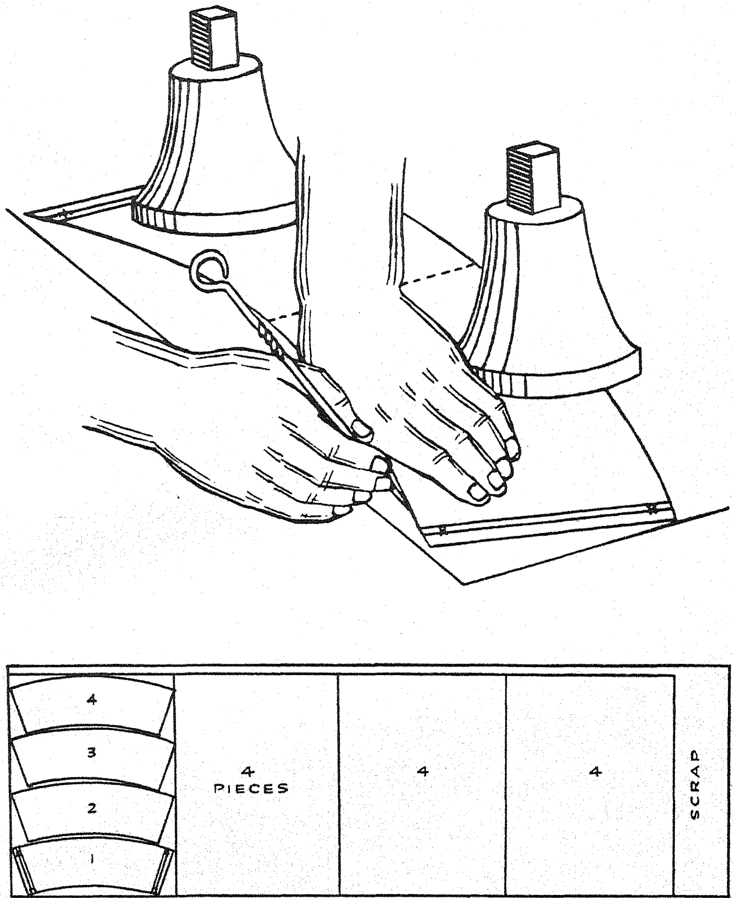


Figure 264.—Transferring the pattern to metal.

If you were in a large production shop where you made the same piece over and over again, you would make a metal pattern and use it to trace around and locate break lines and holes. Generally, the work you will be doing will be so varied that you will develop the stretchout when you need it, instead of making metal patterns for future use.

LAYING OUT SECTIONS FOR VENTILATION SYSTEMS

You'll be using many of the layout procedures discussed in this chapter when you have to replace or repair sections of the VENTILATION SYSTEMS of your ship. You won't find many ships in the Navy today that have natural draft ventilation systems. Some of the older vessels may have, but the modern ship's ventilation is provided by motor driven blowers. These ventilation systems are designed to serve spaces between main transverse bulkheads, and are not interconnected between these watertight sections of the ship. Each section of the ship is served by two distinct systems. One is the supply system which forces fresh air into the compartment it serves. The other system is the exhaust, and this system draws the foul air from the compartment and discharges it overboard. The supply and the exhaust systems are separate from each other, but they work in conjunction with each other. The number of supply and exhaust systems serving your ship will depend on the size of the ship. Figure 265 illustrates one of the ventilation systems aboard a modern ship. Only a few ventilation systems will be found on small ships but a large number of systems will be required to serve a battleship. Valves are fitted in both systems to prevent the spread of water by way of the ventilation lines from a lower compartment that has been damaged to one above it. You are required to know the location of these valves so that you can secure them in the event of an emergency. Familiarize yourself with the ventilation system of your ship, particularly that section which is within the boundary of your damage-control station.

INSTALLING INSULATION OR LAGGING might be a part of your job. Ventilation systems are often fitted with heaters and

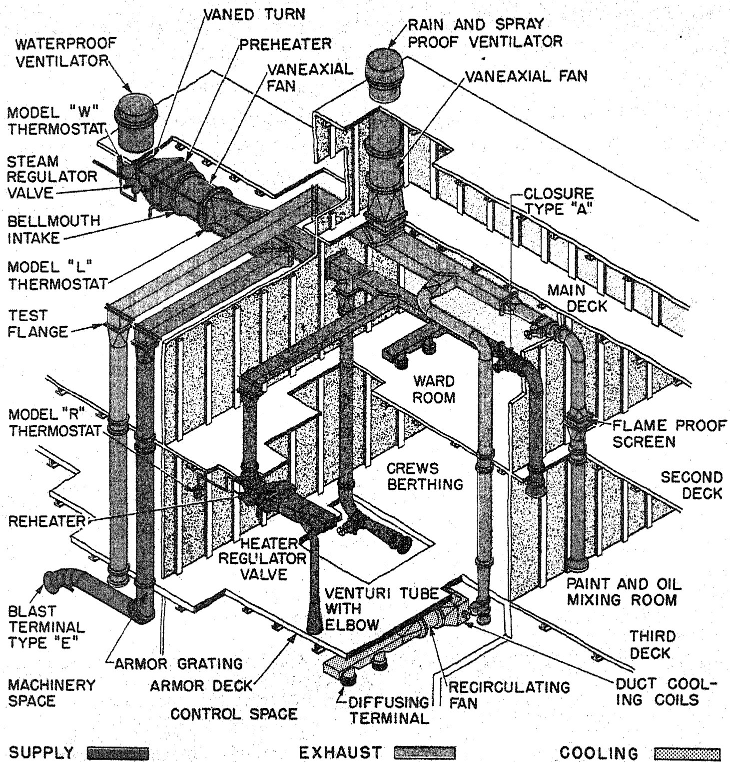


Figure 265.—Ventilation systems.

coolers particularly in submarines, which have extensive air-conditioning plants. Many of the ventilation lines must be insulated and lagged (covered with insulating material) to combat condensation or "sweating." There are many types of insulating materials available for various purposes. (See chapter 39, *Thermal Insulation*, *Bureau Of Ships Manual*, NavShips 250-000-39, 1947.) The insulating materials you will most frequently use are fibrous-glass batt insulation, and fibrous-glass tape. Adhesive insulation cement type B of Navy Department Specification 52C23 is suitable for securing all lagging materials. It has the best properties of adhesion and will not corrode steel

when it is applied to it. Ducts are insulated by applying adhesive cement on the underside of flat surfaces and other necessary locations, and placing the fibrous glass blanket, Navy Department Specification 32G5, around the duct and tying the fibrous glass in place with cord or wire to prevent shifting while lagging the duct. Where preferred, the fibrous glass insulation on fittings and small ducts may be lagged with fibrous glass tape, *Navy Department Specification* 32G9, instead of with the sewed-on glass cloth. After installation the lagging on the ducts is painted to match the other surfaces in the compartment.

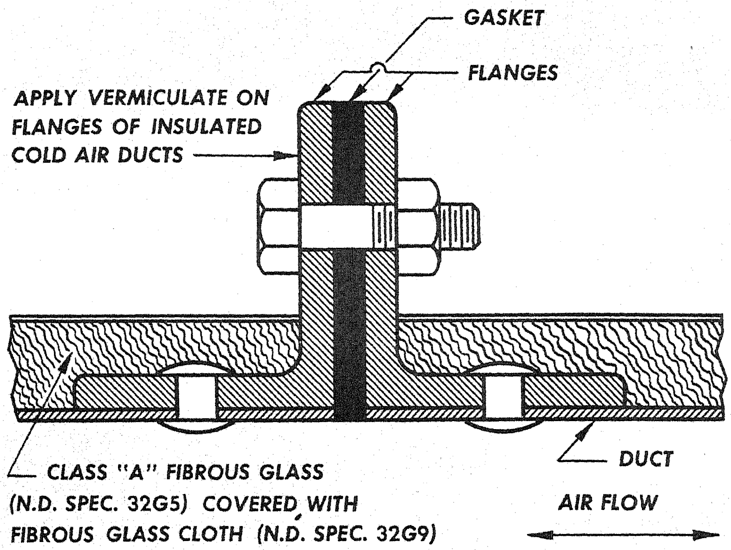


Figure 266.—Method of insulating ducts and flanges.

In good sheet metal work, the primary requirement is to be able to plan and lay out the work. The man who can do this job is the one that is going to get ahead. If your curiosity is aroused, this book has served its purpose. You are now ready to collect some reading material and really give this problem of layout and sketching some serious thought. Get hold of *Use of Blueprints*, NavPers 10621 a basic Navy Training Course, and master it. If you still have curiosity, and you will

if you go this far, check with your educational officer and he can probably furnish you with USAFI courses in this field. Your chief will be glad to help you to get access to books that you want, if he knows you are sincere in your desire to learn.

QUIZ

Column A is a list of layout tools; column B is a list of layout operations. Match items in column A with column B.

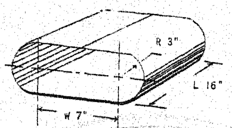
A	*B*
(*a*) Combination square.	1. Transfer dimensions.
(*b*) Dividers or trammel.	2. Construct right angles and parallel lines from base line.
(*c*) Flat steel square.	3. Construct angles other than 90° or 45° from base line.
(*d*) Prick punch.	4. Construct 90° angles, 45° angles.
(*e*) Protractor.	5. Draw accurate lines on metal.
(*f*) Scriber.	6. Lay out long straight lines.
(*g*) Straightedge.	7. Locating points for placing divider legs.
	8. Scribe regular arcs.

Select the one best answer to each of the following statements and write the small letter which is to the left of this answer on the line at the right of the item number.

9. The shape of a cylindrical stretchout will be—
   (*a*) Circular.
   (*b*) Three-dimensional.
   (*c*) Rectangular.
   (*d*) Cubical.

10. The longest stretchout dimension (disregarding seams) of a cylindrical pipe which is $1\frac{1}{2}$ feet long and 6 inches in diameter will be—
   (*a*) 6.0 inches.
   (*b*) 9.4248 inches.
   (*c*) 18.0 inches.
   (*d*) 18.8496 inches.

11. The longest stretchout dimension for the illustrated cylinder variation, if one inch is allowed for seams, will be—
   (*a*) 24.5673 inches.
   (*b*) 36.2832 inches.
   (*c*) 39.5664 inches.
   (*d*) 33.8496 inches.



12. A rough outline of a structure to be fabricated, giving dimensions and details of the job to be done, is called a—
   (a) Tracing.
   (b) Sketch.
   (c) Drawing.
   (d) Blueprint.

13. When working with thin metal, the allowance for a wire edge is how many times the diameter of the wire?
   (a) 1½.
   (b) 2.
   (c) 2½.
   (d) 3½.

14. Rivets for a lap seam must be set in how many rivet diameters from the edge?
   (a) 1.
   (b) 1½.
   (c) 2.
   (d) 2½.

15. The allowance for a lap seam which is to be riveted with ⅛ inch rivets will be—
   (a) ⅛ inch.
   (b) ¼ inch.
   (c) ½ inch.
   (d) ¾ inch.

16. When making a corner lap seam, allowance for clearance should be—
   (a) 1/16 inch.
   (b) 2½ times rivet diameter.
   (c) 4 times rivet diameter.
   (d) ½ the lap width.

17. Of the following, the type seam used for the construction of cylindrical shapes would be—
   (a) Offset lap.
   (b) Plain lap.
   (c) Pittsburgh lock.
   (d) Grooved.

18. If a 5/16 inch grooved seam is specified, the allowance to be added to each edge will be—
   (a) 5/32 inch.
   (b) 5/16 inch.
   (c) 15/32 inch.
   (d) 15/16 inch.

19. With reference to the pocket depth in a Pittsburgh lock seam, the width of the flanged edge must be—

(*a*) More.
(*b*) The same.
(*c*) Less.
(*d*) Two times the pocket depth.

20. When a single hem edge is to meet at a 90° angle, the type of notch used will be—

(*a*) Square.
(*b*) Slant.
(*c*) V.
(*d*) Wire.

21. If an inside flange is to be made on an angle of less than 90°, the notch which will provide flush joints is a—

(*a*) Modified V.
(*b*) Wire.
(*c*) Slant.
(*d*) V.

22. The depth of a wire notch from the edge of the pattern will be—

(*a*) 1½ times the width of the seam.
(*b*) 2 times the width of the seam.
(*c*) 2½ times the diameter of the wire.
(*d*) 3½ times the diameter of the wire.

23. The shape of a wire notch will depend upon the—

(*a*) Type of wire.
(*b*) Size of wire.
(*c*) Type of seam.
(*d*) Size of seam.

24. The method used to develop a pattern for an intersected pipe is—

(*a*) Parallel.
(*b*) Radial.
(*c*) Angular.
(*d*) Triangular.

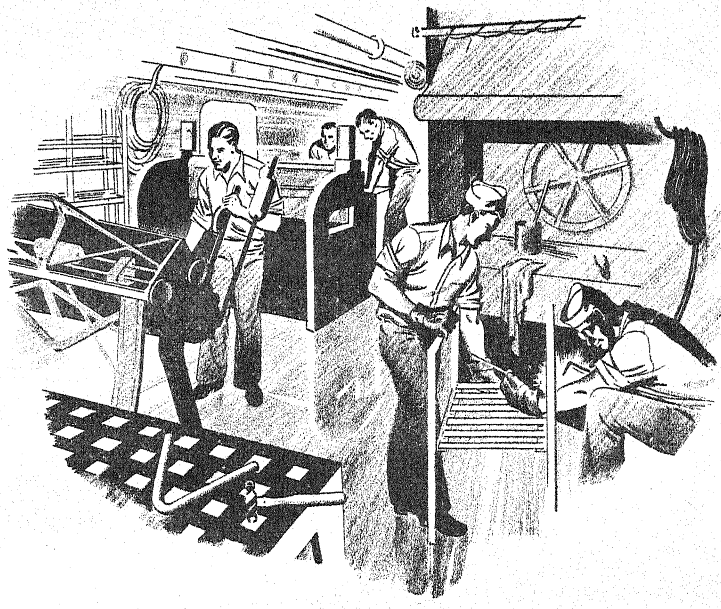
25. The method used to develop a pattern for a funnel would be—

(*a*) Parallel.
(*b*) Radial.
(*c*) Angular.
(*d*) Triangular.

26. Bend lines on sheetmetal are called—
   (*a*) Drawing lines.
   (*b*) Center lines.
   (*c*) Projection lines.
   (*d*) Break lines.

27. Installing of insulation on ship ventilation lines is referred to as—
   (*a*) Sweating.
   (*b*) Caulking.
   (*c*) Lagging.
   (*d*) Sealing.

28. Insulation is installed on ship ventilation lines to—
   (*a*) Combat condensation.
   (*b*) Aid in cooling.
   (*c*) Serve as a fire protection.
   (*d*) Counteract static electricity.



CHAPTER 12

HAND AND MACHINE PROCESSES IN SHEET METAL WORK

When you start any job in sheet metal work, there are several things that you always have to think about before you can actually begin work. Some of these are: materials, layout procedures, forming processes, and tools needed. In other words, you have to know what you have to work with, how you are going to plan the job, how you are going to do it once it has been planned, and just what tools are going to be required to do the job.

In many cases, the material you will use will be determined for you, either by written or oral specifications. When you work from blueprints or plans, the material is usually specified. You'll find it right on the blueprints. In other instances you'll have to find out from the person giving you the job just what kind of metal he requires and what gage or thickness of metal is desired. As you gain experience, you'll have less trouble

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determining the gage metal to use on a job, if it is left up to you to decide. Generally speaking, the shape of the object will determine the method of layout and the forming processes that you will use. The use to which the object is to be put will determine the kind of material best suited for the job.

You'll work with sheets made of black iron, galvanized iron or steel, aluminum, monel, copper-nickel, corrosion-resisting steel, copper, brass, zinc, plate, and terneplate. The greatest portion of your work will be with galvanized (zinc-coated) sheets and black iron (sheets that do not have a protective coating). Regardless of the material used the layout procedure will be about the same.

It's common practice in the sheet-metal field to specify the thickness of sheet metal by gage number. The practice in the supply department of the Navy, though, is to order sheet metal in terms of weight per square foot. For that reason it is important that you be able to recognize a particular sheet of metal by its weight per square foot and its thickness in decimal parts of an inch as well as by gage number. Figure 267 is a conversion table that will come in handy for ready reference when you need to convert galvanized iron or black iron sheet gage to thickness in inches or to weight per square foot. The approximately 40 pounds per square foot for each inch of thickness will vary from five percent above to five percent below that given in the table. The sheets you work on may have the gage number stencilled on them by the manufacturer; but in case it isn't and you need to know it, you'll have to determine the gage by measurement. You can do this by measuring the thickness of the sheet with a U. S. standard gage for sheet and plate iron and steel. It's a good idea to check the sheet whether it is stencilled or not. Get the habit of checking and you'll save a lot of errors. Steel plate heavier than 11 gage is usually designated in weight per square foot. For example, steel plate ⅛-inch thick is referred to as 5-pound plate, ½-inch thick as 20-pound plate, 1-inch thick as 40-pound plate. This practice is based on the fact that steel weighs approximately 40 pounds per square foot for each inch of thickness, the rule being 2½ pounds for each 1/16-inch thickness.

GAGE U. S.	BLACK IRON		GALVANIZED IRON
	Thickness Inches	Wt. in Lbs. per Sq. Ft.	Wt. in Lbs. per Sq. Ft.
32	.0097	.406	.563
30	.0120	.500	.656
28	.0149	.625	.781
26	.0179	.750	.906
24	.0239	1.000	1.156
22	.0299	1.250	1.406
20	.0359	1.500	1.656
18	.0478	2.000	2.156
16	.0598	2.500	2.656
14	.0749	3.125	3.281
12	.1046	4.375	4.531
10	.1345	5.625	5.781

Figure 267.—Conversion table.

Your first step in any sheet-metal job is the selection of material. Sometimes material is specified in your plans. Next, you'll lay out your work either directly on the sheet or plate or on template paper. If you've made your developments on paper, be very careful to transfer the pattern accurately to the sheet. After all of your layout lines are drawn, your next step is to cut and notch the sheet before forming.

Sheet metal is tricky stuff to work with, especially when you're bending or forming it. You'll learn mostly by experience just how much and in what way you can bend and form the various kinds of sheet material. You'll also learn to be extremely careful when you handle sheet metal edges, because it is an easy way to cut your fingers. It's a good policy to dress (smooth) a fresh cut metal edge with a file.

HAND AND MACHINE CUTTING

If your material is light gage sheet metal, you'll make your cuts with hand snips. For 22-gage or lighter mild steel, use straight or combination snips. For 16- to 20-gage mild steel, use bulldog snips. Material heavier than 16-gage may require the use of bench shears like the ones shown in figure 268.

Select the proper snip for the job at hand, see that it is properly adjusted and oiled, and you'll make your task a lot easier. Start your cut with the jaws open as far as it is convenient for you to grip. Keep the blades at right angles to the work, and

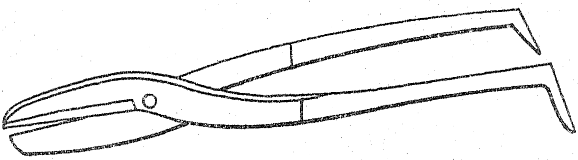

Figure 268. — Bench shears.

cut the sheet by closing the blades just short of the full length to prevent leaving jagged edges. Finish the cut, keeping the snips on the line.

You can cut an outside circle as well as a straight-line cut with the combination snips. Cut off the corners of the metal to make it easier to handle. Then make a continuous cut,

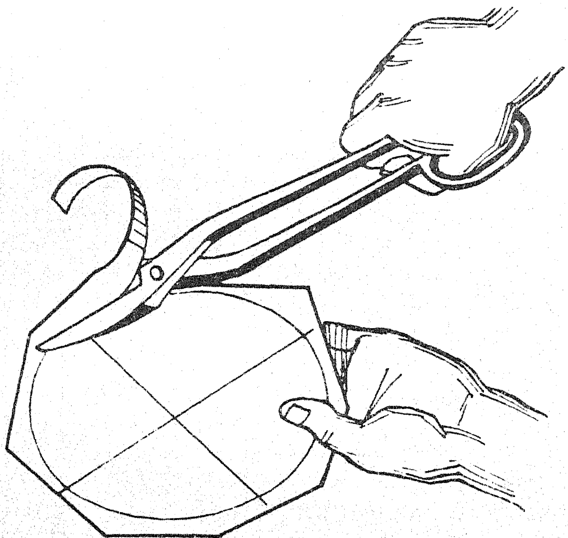

Figure 269. — Cutting an outside circle with combination snips.

turning the metal as the cut is being made. If possible, remove the waste material in one piece.

When you have an inside circle to cut, you'll use hawksbill, aviation, or pivoter snips. To start the cut you'll have to punch a hole in the center of the circle to be cut, work out to the line, and then follow the line around until the cut is completed. The pivoter snip is one of the handiest hand cutting tools in your shop. You can easily cut irregular curves as well as straight lines with it.

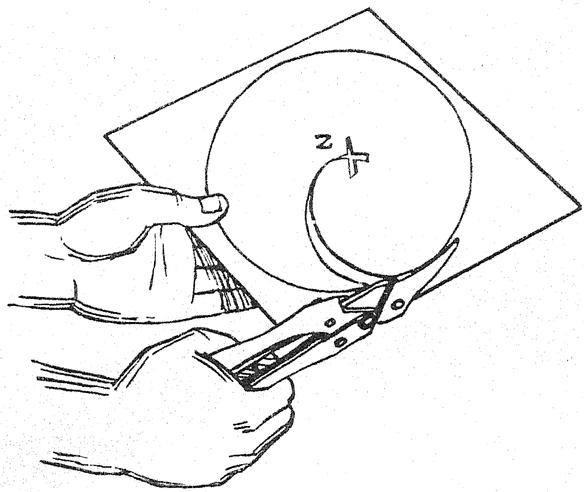

Figure 270.— Cutting an inside circle with aviation snips.

Remember, that unless otherwise identified, these hand cutting tools are designed for light-gage soft steels. When you are working with stainless steel and others of the special alloy sheets, you'll have to do your cutting with special alloy snips. These snips have inlaid cutting edges of special alloy tool steel, and are rugged and tough enough to shear sheets that would nick and dull the cutting edges of ordinary snips.

POWER SQUARING SHEARS for long straight cuts on heavy materials will be available if you are on one of the larger vessels. Depending upon the size of the shop and the work your shop is

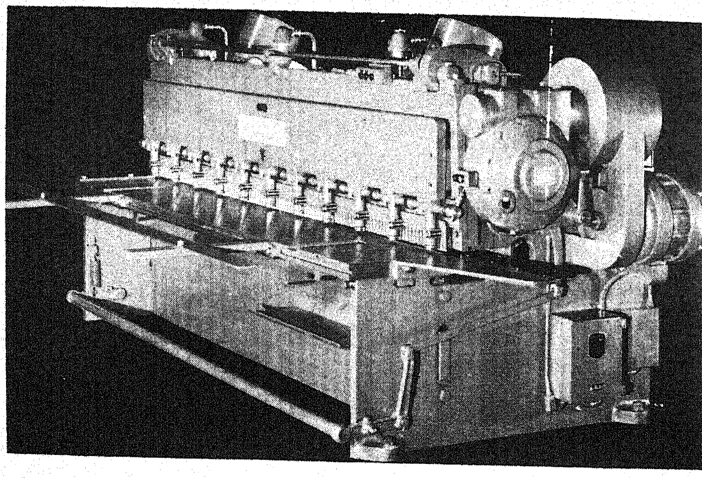

Figure 271. — Power squaring shears.

designed to do, this machine will vary in size from large power-driven shears like the one shown in figure 271 to the smaller, treadle-operated, shears like the one shown in figure 272.

These shears are designed for various capacities, and the capacity of the shear must not be exceeded or the machine will be put out of order. Capacity plates, specifying the maximum thickness of material to be cut, are installed on the machine when it is manufactured. Do not remove these plates. The man who uses the machine next may not know as much about it as you do, and he'll need to know the maximum capacity of the shear also. Don't expect the machine to cut alloy sheet steels of the same gage as the capacity gage for soft sheet. Alloy steels are tough and will dull the blade. These sheets have greater shear strength than mild steel sheets of the same thickness. Greater force is necessary to cut the material. Therefore, you shouldn't try to cut alloy steel more than half the thickness of the maximum capacity for which your shear is built, if the capacity rating is set up in terms of mild steel gage.

Squaring shears are equipped with devices which are used as stops for sheets when more than one piece of the same size is

required. These stops or gages are located on the front, back, and sides of the bed of the shear. They can be adjusted to various lengths and angles (see figure 272). The gages of all types of squaring shears are similar, whether the machine is

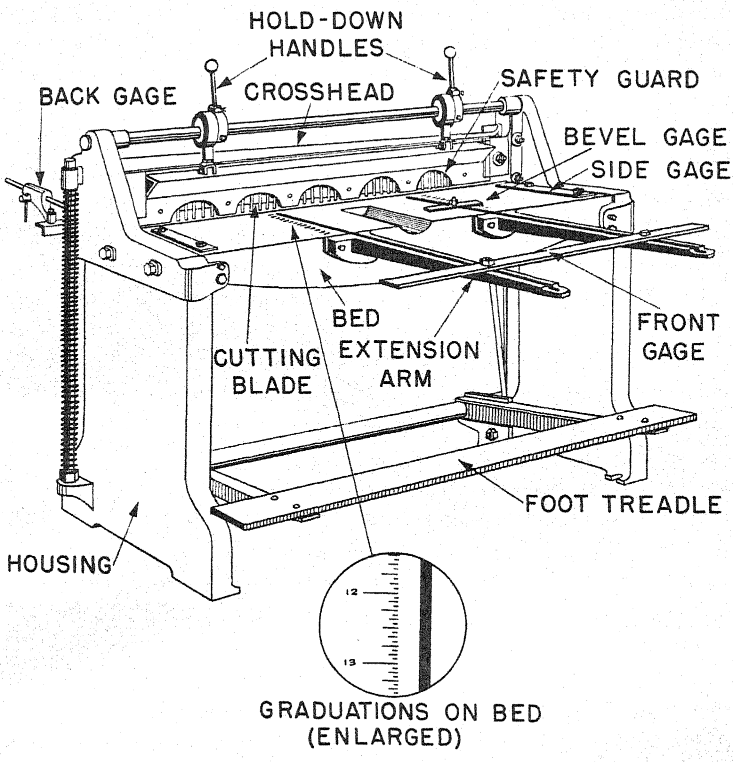

Figure 272.—Treadle-operated squaring shears.

manually operated or power driven. When trimming so as to form a square sheet, the side gages must be set at 90° to the cutting blade. You can do this by placing the tongue edge of a flat steel square against the shear blade, and lining up the side gage with the body of the square. When the side gage is securely bolted in position, and your metal sheet held firmly

against the side gage, the newly cut edge will be at 90° to the side of the sheet.

There are two types of squaring shears—one with an attachment to clamp the sheet automatically, and the other with an attachment to clamp the sheet by hand. These clamping devices are known as hold-downs. On power-driven shears the hold-down is automatic. When you've started the motor, give it time to reach maximum speed, and insert the metal to be cut. Now all you have to do is trip the foot treadle, and the machine automatically clamps the sheet into position and makes the cut. With the hand-operated hold-down, which is usually set up with manually operated machines, the sheet to be cut is inserted into the shear, the hold-down handles adjusted, and the cut is then made by depressing the foot treadle (see figure 272). After the cut is made, you then release the hold-downs and remove the piece from the machine.

Not all squaring shears have a safety guard, but all should have one. If you are fortunate enough to have one on your machine, don't remove it. The safety guard has saved many a finger for Uncle Sam's Metalsmiths. No one would stick his finger in the machine intentionally, but accidents do happen, and the safety guard is just one more precaution that is well worth having. The shear should be operated by one man, but if two men are required for the job, extra care is needed to prevent accidents. If you are operating the treadle, be sure that your helper has his fingers clear before you depress the treadle.

The squaring shear, whether operated by power or hand, is designed to cut SHEETS OF METAL. Never cut square, round, or bar stock with this machine. You'll nick and dull the blade and otherwise seriously damage the machine. There are various other types of shears that will cut this type of stock. Also, you'll have saws for doing this type of cutting.

The principle of the shear is the same as that of the guillotine used during the French Revolution to cut the heads from so many unfortunate victims. The lower blade of the shear is set in a position parallel to the bed of the machine, and it remains in a stationary position at all times. The upper blade, which is the movable blade, is attached to the cross head at a slight

angle to the horizontal position of the lower blade. The shearing action starts at one end of the sheet and continues across the sheet in the same manner that a pair of scissors cuts paper or cloth.

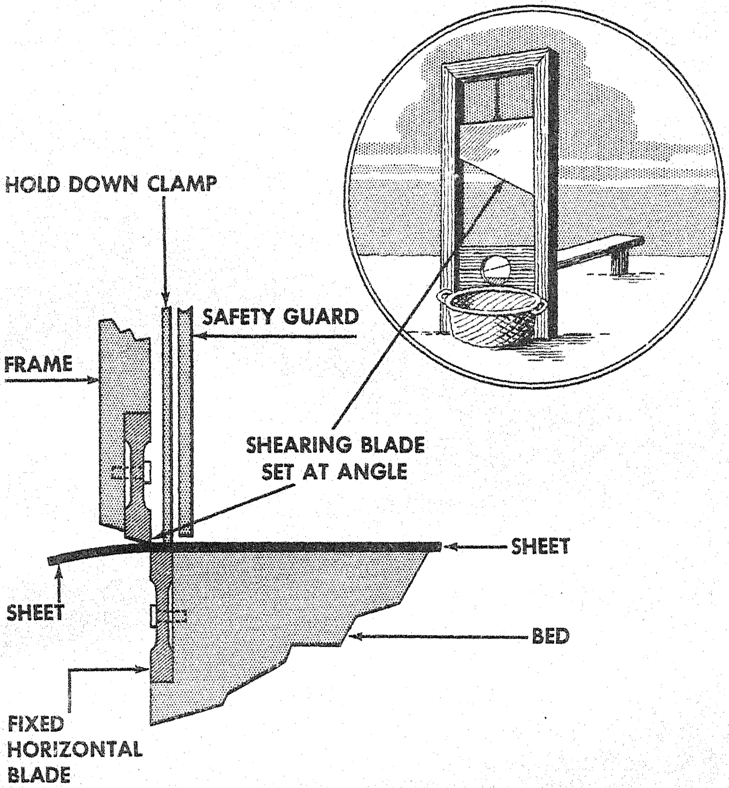

Figure 273.— Principle of the shear.

Metal rules or other tools should never be left on the shear bed. They might slide under the blade and dull it or spring some of the shear parts. Besides, a rule or square that has been cut in two has lost its usefulness.

A UNISHEAR is used for cutting sheet-metal curves and

notches, as well as for straight-line cutting. Unishears might be called power-operated, combination snips. This handy machine has two short blades. The lower blade is held in a fixed position, and the upper blade moves up and down at high speed. The tool will cut metal up to its rated capacity. Do not exceed this rated capacity. The unishear is designed in a variety of sizes, the most common being 18-gage and 12-gage soft steel capacities.

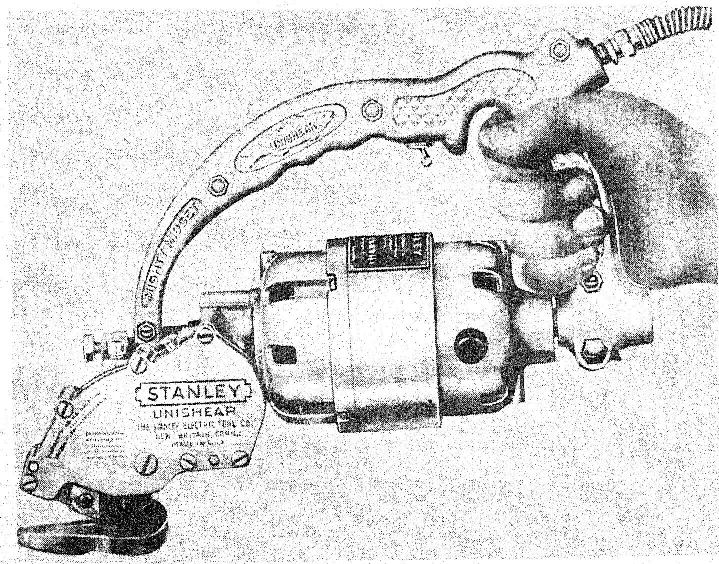

Figure 274.— An 18-gage unishear.

A stationary bench tool can be made of the unishear by securing the tool in the cradle. The cutting blades are easily removed for sharpening and replacement. The machine will cut as fast as you feed it, up to 15 feet per minute. The unishear is a versatile machine. It is ruggedly constructed, but to get the best out of it, you'll have to give it proper care. Treat it right and it'll treat you right. Keep it clean, keep it oiled, and you can make a cut in the same manner and in half the time that it would take with a pair of hand snips.

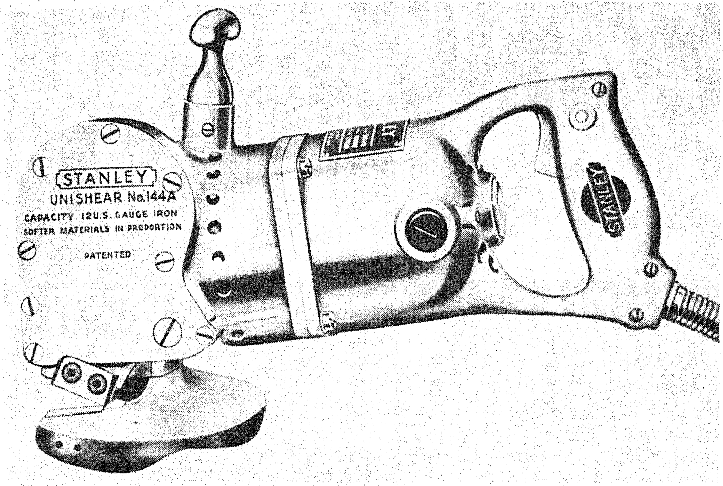

Figure 275.—A 12-gage unishear.

You know how to cut an outside and inside circle with a pair of hand snips. So long as the gage of the sheet is relatively light, it is probably the best method available. When you have heavier gages of metal to work, however, it becomes quite a task to use the hand snips. There are a number of machines, both manual and power-operated, that speed up and ease the cutting operation. You may be fortunate enough to have some of them available on small vessels, and you are sure to have some and perhaps all of them on the larger ships. Included among these shearing machines are slitting, throatless, circle, and ring-and-circle shears. Slitting shears and throatless shears are discussed in Chapter 2, Tools and Equipment.

With the RING-AND-CIRCLE SHEAR, the problem of cutting perfect outside and inside circles is greatly simplified. All you need to do is—

1. Select a piece of stock of sufficient size and locate the center with a prick-punch mark.
2. Adjust the gage arm of the machine to the radius of the desired circle.

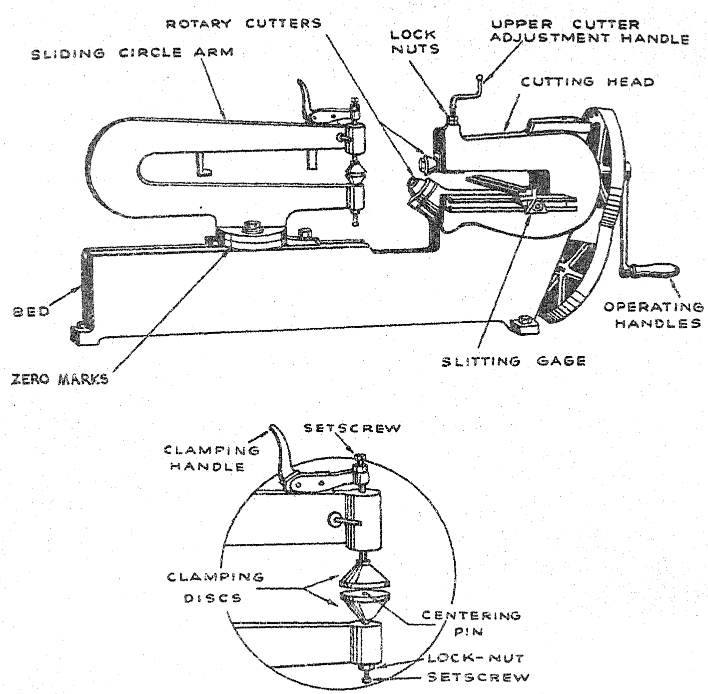

Figure 276.—Ring-and-circle shear.

3. Put the stock in the sliding circle arm, locating the center by feeling the centering pin of the clamping device slip into the depression of the prick-punch mark.
4. Lock the metal blank securely in position by depressing the clamping handle.
5. Set the lock nuts on the upper cutter-adjustment handle so that the upper cutter, in its lowest position, produces a clean cut.
6. Lower the upper rotary cutter (figure 276) until it comes in firm contact with the metal.
7. Turn the operating handle (if power-operated, just push the starting button). The blank will feed itself into the shear. Continue the operation, lowering the upper rotary cutter until the disk is cut, and you've cut a perfect circle.

If your purpose is to manufacture a flange or circular ring of the disk, you cut the inner circle in the same manner as the outside circle was cut. Just raise the upper cutter by turning the handle controlling it. Adjust the sliding circle arm to the new radius for the inner circle, and proceed as with the outer circle.

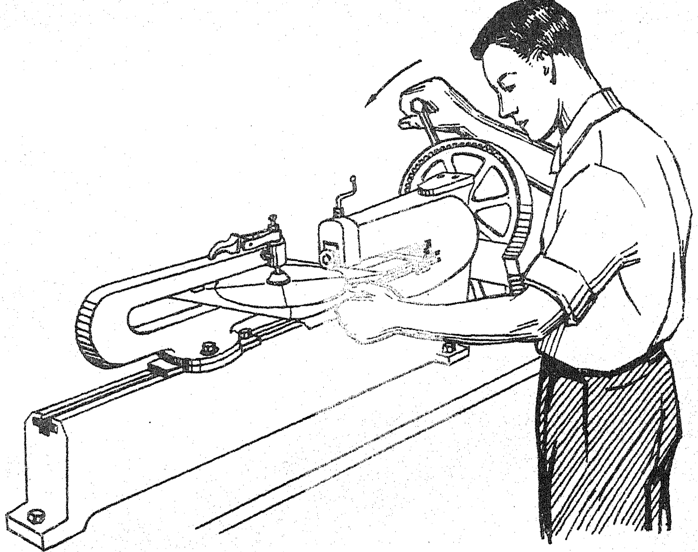

Figure 277.— Working with ring and circle shear.

The ring-and-circle shear can be used to cut straight or irregular curved sections. When cutting straight sections, use the slitting gage, and for irregular curves just follow your layout line. For light-gage materials, the rotary cutters should be set to just touch, but not rub. For heavier gages, the cutters should be separated slightly. These adjustments should be made according to the manufacturer's recommendations. Check your instruction sheet for details of the machine you have available.

If you have to make a ring or a flange from 11-gage material, and the only tools that you have to work with are hand tools and a slitting or bench shear, you're going to do a great deal

more manual labor than you would if you could use a ring and circle shear. But you can make the ring in the following manner:

1. Scribe concentric circles (circles of different size having the same center) of the desired radii for the inner and outer circumferences.
2. Make a series of straight cuts on the slitting shear as close to the outside circumference line as possible.

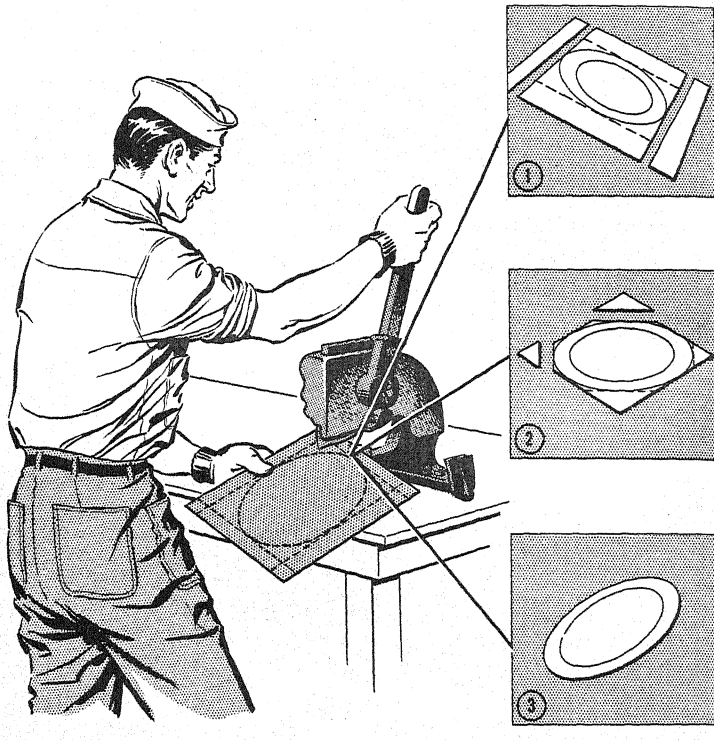

Figure 278.— Cutting outside of circle with slitting or bench shear.

3. File or grind the outer circumference down to the line.
4. Drill, punch, or chisel the inner "waste material" from the disk.

5. Secure the ring in the vise and file the inner circumference to the inner scribed line.

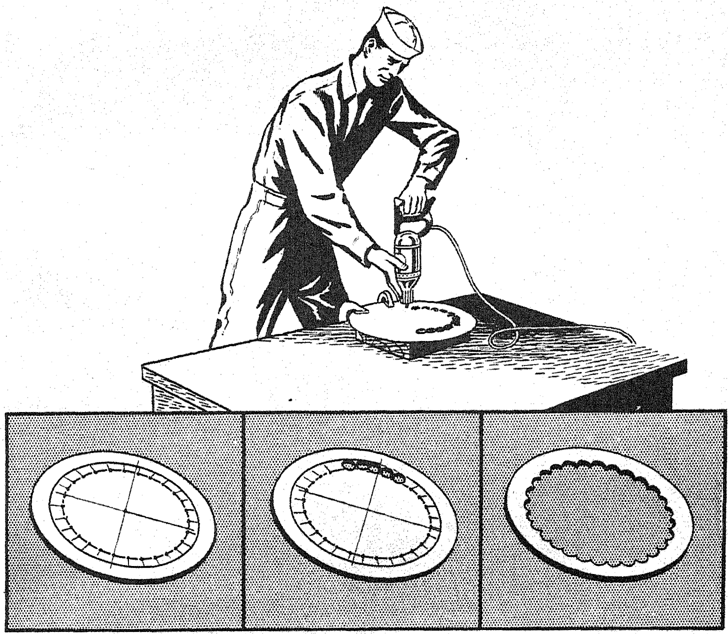

Figure 279.— Drilling holes around inner circumference.

SHEET METAL FORMING

The next step after cutting and trimming your stretchout is the forming process. Again the equipment you have at hand will determine the exact procedure you will use. Figure 281 illustrates a bend made by clamping the sheet on the workbench or other object, with an angle bar and **C**-clamps. You form the bend by bending the metal slightly with your hands, the entire length of the sheet, and finishing the bend with blows struck with a wooden mallet.

The more experience you have in making bends in this manner, the better the appearance of the bend will be. In all prob-

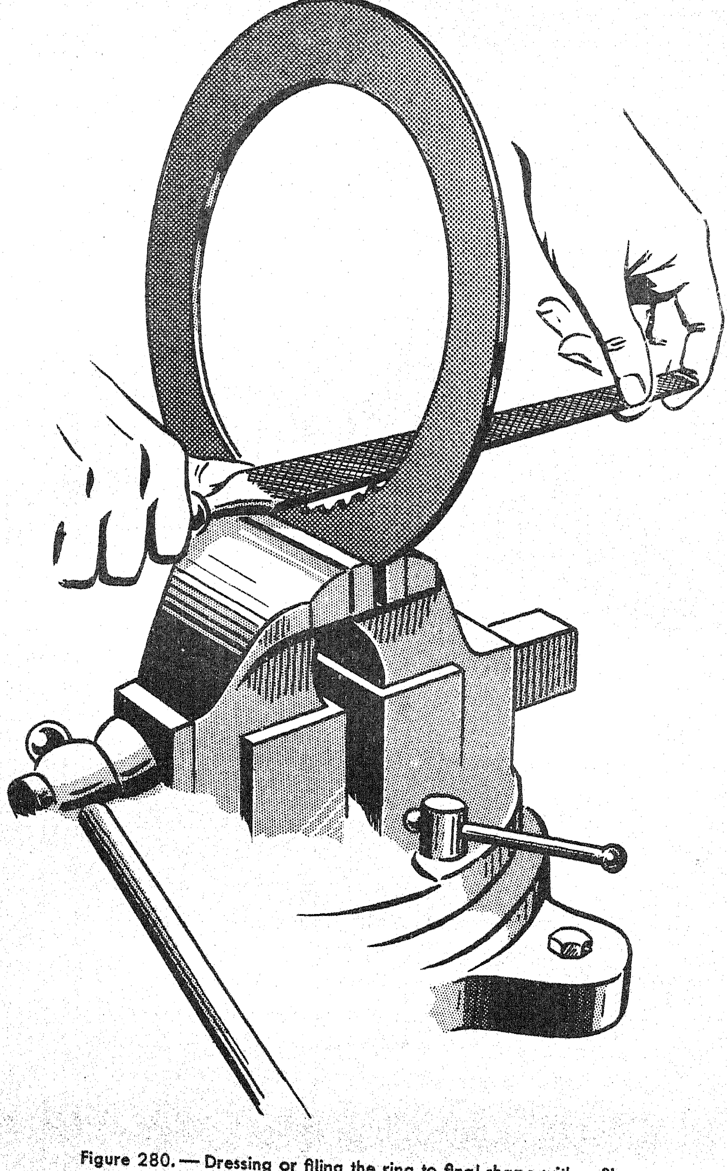

Figure 280.—Dressing or filing the ring to final shape with a file.

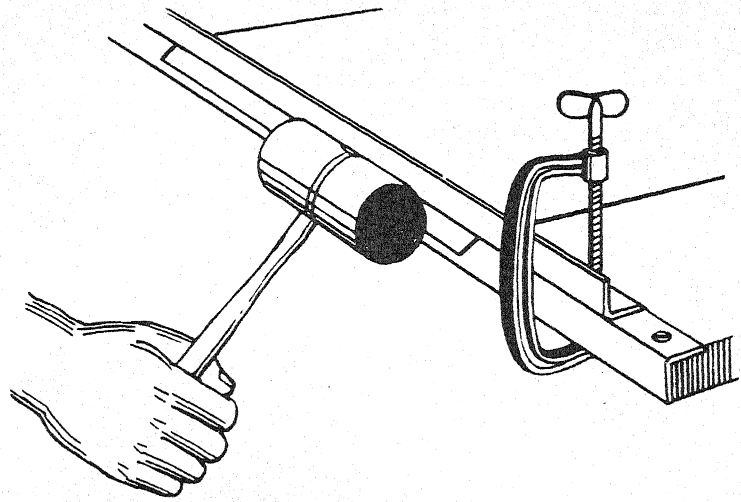

Figure 281.—Making a bend by hand.

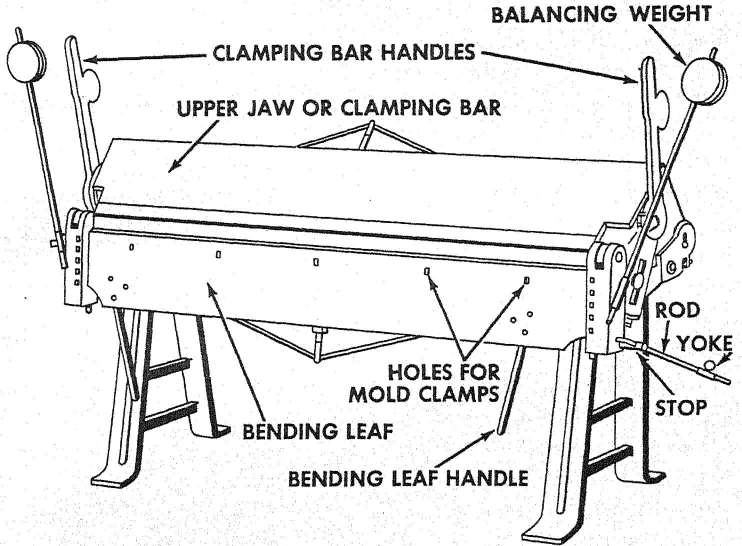

Figure 282.—Standard cornice brakes.

ability, though, you'll have a standard cornice or box-and-pan brake.

Standard cornice or box-and-pan brakes speed up the work and produce more uniform bends than can be produced by hand. These machines are ruggedly constructed and will give lifetime service if you use them properly within their rated capacity. Before you make a bend with the machine, you have two things to do in addition to making sure that the stock or sheet you are working is not beyond the rated capacity of the brake.

1. Adjust the clamping adjustment screw for the gage metal you are working. (The clamping device holds the work firmly in position.)
2. Adjust the upper leaf (move backward or forward) to at least the thickness of the metal. This distance is measured from the front edge of the lower jaw to the front edge of the upper jaw.

It's important that you make these adjustments. For example, if your clamping device is set for 18-gage metal and you make a bend in 24-gage metal, your sheet may not be held firmly in position and it is likely to slip. This would cause the bend to be made in the wrong place. On the other hand, if the brake is adjusted to clamp a very thin sheet of metal and a thick sheet is inserted for bending, you may break the clamping handle because of the strain exerted in attempting to close the jaws of the brake.

When you have not adjusted the upper leaf correctly, you'll do still more serious damage. As an example—if you have adjusted the upper leaf for 24-gage (moved it backward or forward a distance equal to the thickness of the sheet from the front edge of the lower jaw to the front edge of the upper jaw) and then inserted a sheet of 18-gage metal to make a bend with his setting, you will put undue strain on the jaws of the machine. Possibly this strain could spring the jaws out of alignment and damage the edges of the jaws. No damage will be done if the brake is set for heavy gage and you bend light-gage metal with the same setting. The bend will not be as sharp and

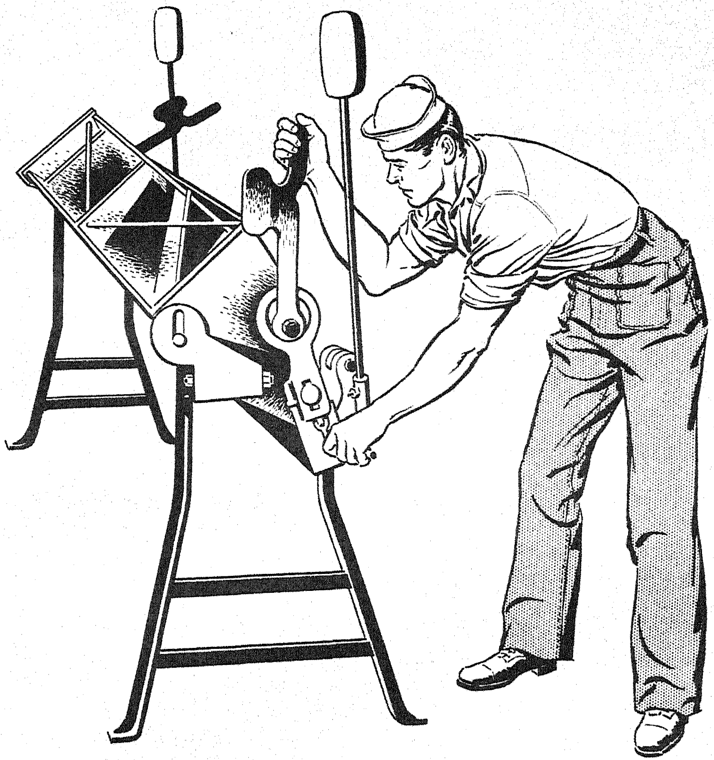

Figure 283.— End view of brake showing adjustment screws.

it will have a radius. A radius is often desirable, and this is the way that a bend with a slight radius is formed. For a sharp 90° bend, the upper leaf must be adjusted so that the distance is exactly the thickness of the metal.

Standard hand brakes are rated for a 1-inch or wider flange (bend) on mild steel when the angle bar is in place on the bending leaf. When narrower flanges are to be formed, a correspondingly lighter material must be used. For each ¼-inch reduction in flange size, reduce the thickness of the metal two gages. For instance, a machine is rated to bend a 1-inch flange on 16 gage, a ¾-inch flange on 18 gage, and a ½-inch flange on 20 gage.

Brakes vary in length from 3 feet 1 inch to 10 feet 1 inch and are either hand- or power-operated.

To get the feel of the brake, proceed as follows:

1. Select a piece of 18- or 20-gage scrap sheet metal. Scribe a straight line across the surface.
2. Set the clamping device so that the metal will be held firmly in place without your having to exert too much pressure on the clamping handle.
3. Set the bend allowance on the upper leaf for the metal you are working. This distance is measured from the front edge of the bottom leaf to the front edge of the upper leaf. (See figure 284.)

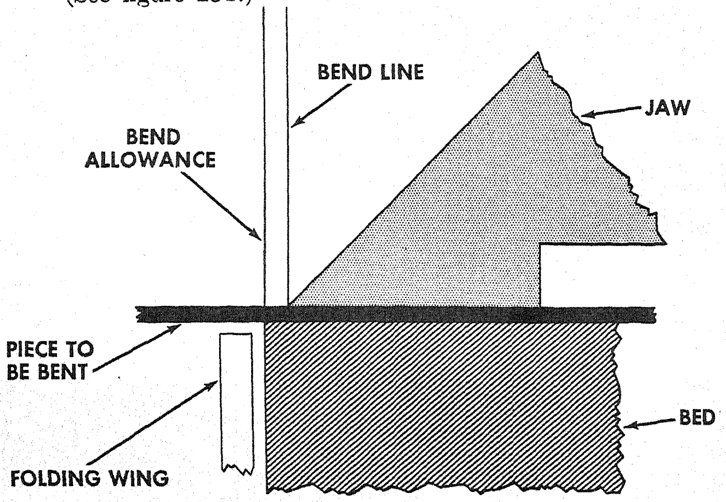

Figure 284.—End view of brake showing bend allowance setting.

When you want to make a sharp bend, the allowance set on the upper jaw is exactly equal to the metal thickness. When your allowance is greater than the thickness of the metal, the bend will have a slight radius.

4. Raise the upper leaf with the clamping handle and insert the sheet in the brake, bringing the scribe line on the sheet into a position even with the front edge of the upper jaw.

5. Clamp the sheet firmly in position. Check to make sure that the brake line (the line you scribed on the sheet) is in line with the upper jaw.
6. Raise the lower leaf to the desired angle to form the bend or flange.

When the metal you bend is soft and ductile (copper, for example), your bend will "stay put" in the angle to which you raised the lower leaf. If the metal is hard and springy, you will have to raise the lower leaf a few degrees more than you do for the soft metal to compensate for the "spring-back" of the harder metal. The exact amount of spring-back for which you will have to compensate will be determined by the metal. Experience will be your instructor, and your eye will be your guide.

If you don't know just how much the metal will spring back, raise the lower leaf to the angle desired. Lower the leaf slightly and observe the amount that the metal springs back. Then raise the leaf again, this time to a greater degree than before, to compensate for the amount of spring-back you observed in the first attempt.

7. Release the clamping device and remove the sheet from the brake.

If, after you have made your bend, you find that one end of the sheet has a sharper angle than the other end, you can be sure that your machine is out of adjustment. Take a look at the bend. If it is sharp at one end and has a radius at the other, it means that the end of the brake that made the bend with a radius needs to be set up slightly. This situation often occurs when the brake has had a great deal of use. Normally, small work is handled on the right side of the brake. Over a long period of time this side receives more wear and must be adjusted to compensate for the wear.

You'll often have to form bends with the same degree of angle on a large number of pieces. To facilitate the operation of making duplicate bends, you will set the stop gage attached to the bending leaf at the end of the brake. The stop gage consists of a rod, yoke, and set screw. When you have made

the first bend to the desired angle and allowed for the spring-back, you set the stop gage. To do this—

1. Raise the bending leaf to the position required to make the desired bend.
2. Slide the yoke (see figure 282) up the rod until it touches the stop through which the rod passes. Tighten the setscrew.

You can now make duplicate bends by raising the leaf until it is halted by the stop gage.

When you are making bends on short sheets of metal it will be necessary to raise only one end of the upper jaw. When your piece is long, both ends will have to be raised to get the metal in the brake. Adjust the sheet in position by lining up the left-hand edge with the brake line and the upper jaw. Clamp in place. Then line up the other end of the sheet and clamp it in position.

The best method to use when forming a single hem (see figure 238) is as follows:

1. Insert the sheet to be hemmed all the way in the brake, lining up the brake line with the front edge of the upper jaw.
2. Raise the lower leaf as far as it will go. (If the stop gage has been set, be sure that the yoke is set far enough toward the end of the rod to permit the leaf to travel the maximum distance.)
3. Lower the leaf, release the clamping device, and remove the sheet from the brake.
4. Close the left side of the brake, allowing the right side to remain open.
5. Insert the left hem edge of the sheet into the brake, holding the sheet with your left hand. Hold the sheet at an angle to the front edge of the brake.
6. Lower the upper leaf with your right hand. This action will flatten that portion of the hem that is between the jaws. (The brake in this instance is used as a press.)
7. Raise the upper leaf and decrease the angle between the

front edge of the brake and the edge of the sheet. When you decrease this angle slightly, you will bring another small portion or "bite" of the hem under the jaws of the brake.

8. Continue lowering and raising the upper jaw, taking small bites of the hem until the entire hem is flattened.

Don't attempt to flatten the entire hem in one operation. When you are hemming metal that has a great deal of spring-back, it may be necessary for you to work down the hem part way with a mallet before you finish it in the brake.

You'll make the double hem in the same manner as you made the single hem. For the lay-out of a double hem, see figure 239, chapter 11. When flattening hems, exert just enough pressure with the clamping-device handle to press the metal together. On the heavier gages of metal it may be necessary to operate the clamping handle up and down several times on each bite in order to make the hem perfectly flat.

In the preceding chapter you learned how to lay out a PITTSBURGH LOCK SEAM. See figure 244 for the layout of this seam. You'll be using the cornice brake to form this seam. Make a layout for a Pittsburgh lock seam on a scrap sheet of metal and form it in the following manner (see figure 285):

1. Insert the sheet in the brake, making the first bend to just a little less than 90°.
2. Remove the sheet. Insert the sheet, flanged edge down, all the way into the brake. Raise the lower leaf to make a maximum possible bend.
3. Remove the sheet from the brake. Turn your sheet so that the side with the 90° angle is up and slide it into the brake until this angle is flush with the forward edge of the upper jaw. Raise the lower leaf through its maximum arc.
4. Raise the upper jaw and slide the sheet farther into the brake until the edge of the sheet is flush with the front edge of the upper jaw.

At this point a strip of metal having the same gage as the metal you are forming, with a length equal to the length of the

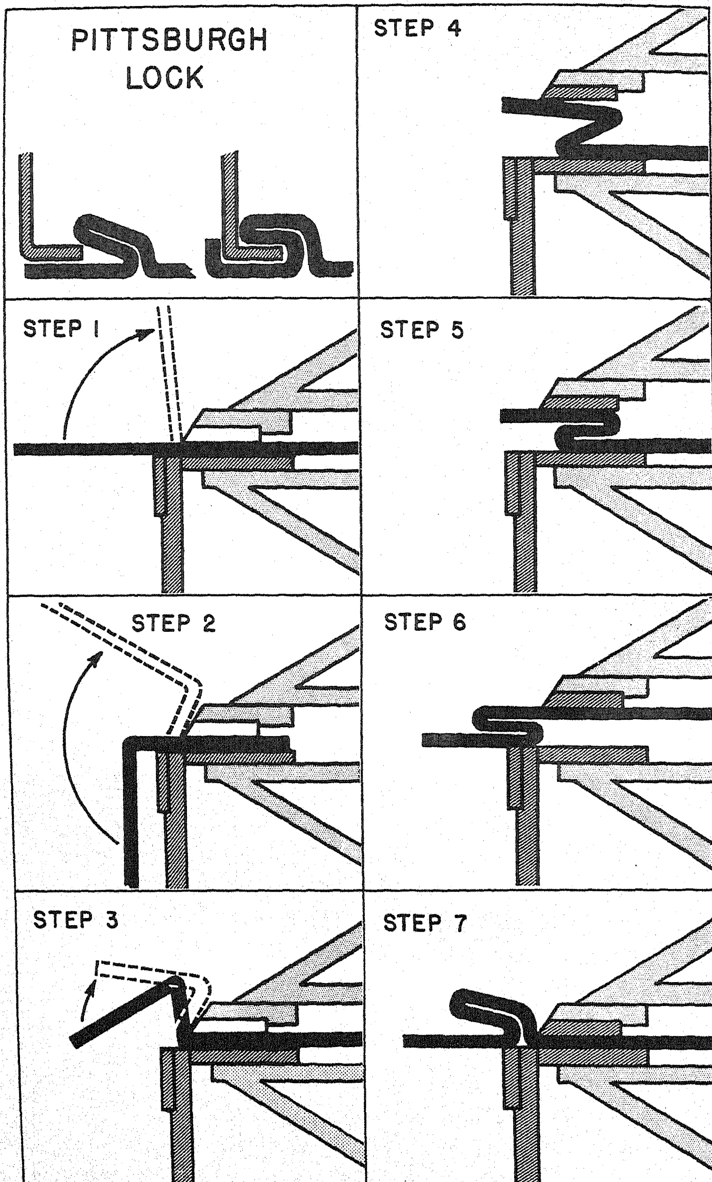

Figure 285.—The Pittsburgh lock seam.

seam (small lengths of stripping may be used) and about an inch wide, is inserted in the recess which will form the pocket of the seam.

5. Then close the left-hand clamping device. Use an easy up-and-down motion with the right-hand clamping device to start pressing the folds of the seam together.
6. After the flattening has been started in this manner, release the right-hand clamping pressure and complete the flattening procedure in the same manner as you did when you made the hems. Be sure that the "bites" you take are not too large.
7. Turn the sheet over and line up the inner bent edge with the front edge of the upper jaw. Lower the upper jaw with the clamping handles.
8. The clamping pressure used in the preceding step will cause the formed edge of the seam to raise slightly. To bring this section back in line, work it down with a wooden mallet.

You have the most difficult portion of the Pittsburgh lock seam formed. The other portion (the part or flange that fits into the pocket) is merely the bending of a 90° angle having the proper flange width. To complete the seam, remove the strips from the pocket. Insert the flanged edge in the pocket, tapping it firmly in place with a mallet or hammer. Bend over the protruding edge with your mallet and the seam is finished.

The Pittsburgh seam is very handy for use on jobs that you have to assemble on "location," away from the shop. The entire job can be formed in the shop and then assembled with a mallet. Jobs on which you'll use this seam are square and rectangular ventilation ducts and elbows, and lockers.

Your brake may or may not be equipped with molds, and unless you do fancy cornice work, you will rarely, if ever, use these molds. You secure these molds to the bottom leaf of the brake by means of friction clamps. Figure 286 illustrates a job ready to be formed over a mold.

Your brake is not an indispensable machine. Almost every job that you can do on it can be done by hand, but with the

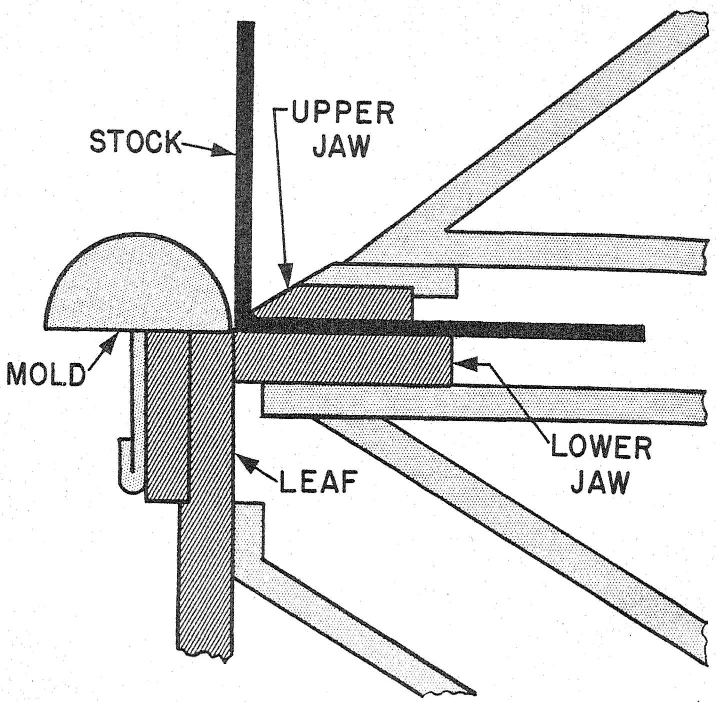

Figure 286.—Cross section of job ready to form over a mold.

brake you can do the job much better and a great deal faster. Keep the working parts well oiled and the jaws free of rust and dirt. If for any reason you have to do any hammering on a job while it's in the brake, take care not to strike the forming edges of the jaws with a hard-faced hammer. If you must "beat" on the metal, use a wooden or rawhide mallet. Some of the types of bends and work that can be accomplished on the brake are illustrated in figure 287.

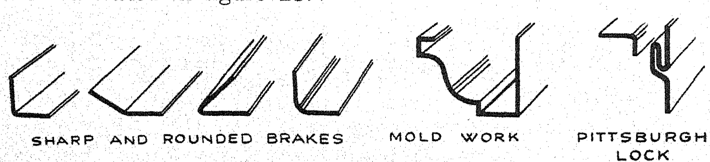

Figure 287.—Types of work done on a brake.

ANOTHER TYPE OF BRAKE, KNOWN AS A FINGER OR UNIVERSAL BOX- AND PAN-BRAKE, (figure 288) is used to advantage in the construction of boxes and lockers. All the work done on a standard cornice brake can be done on the finger brake.

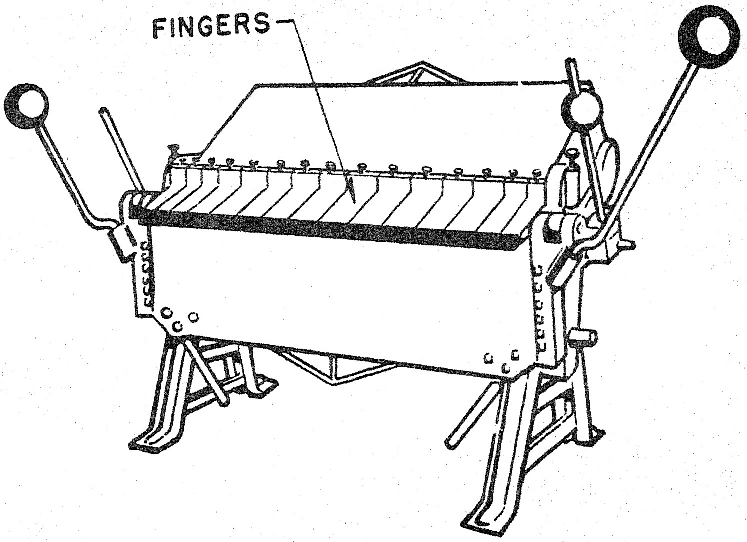

Figure 288.—Box- and pan-brake.

The upper jaw of this brake has removable fingers of varying widths instead of the solid-bar construction of the

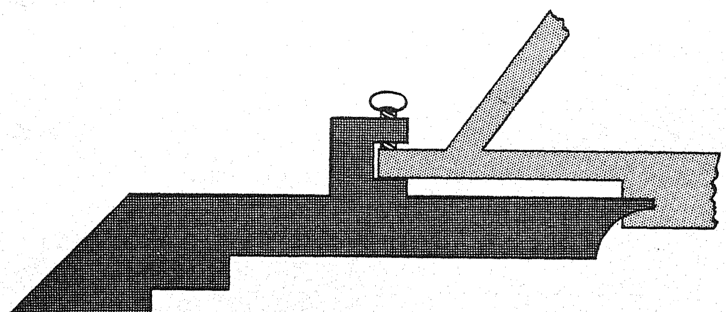

Figure 289.—Detail of finger.

upper leaf of the cornice brake. These steel fingers are secured to the upper leaf by means of a thumbscrew, and the fingers must be securely seated and the screw tightened down before using the brake (figure 289).

If you form a box on a cornice brake, you'll find that you will have to straighten a part of your bend on one side of the box in order to make the last bend. This is where the box and pan brake serves you to greater advantage. You just remove the fingers in those sections of the upper leaf that are in your way, leaving as much of the upper bar as is needed and make the final brake in the usual manner (figure 290).

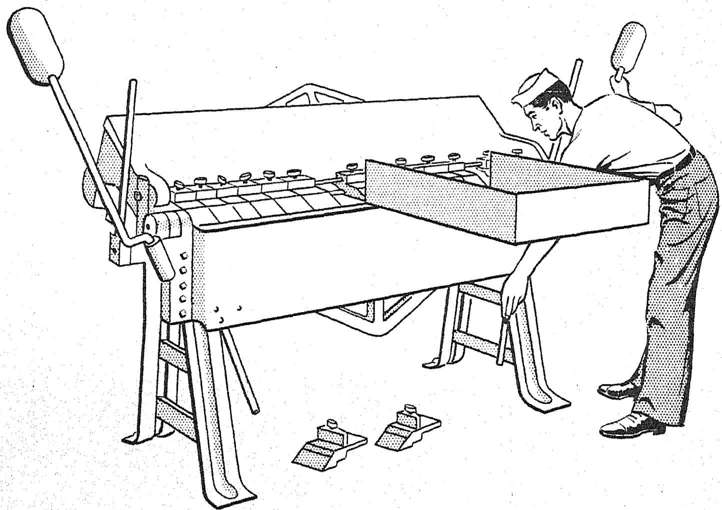

Figure 290. — Using the finger brake.

Before you start any work on the box brake, be sure that all the adjustments are correctly made for the gage of metal you are going to form, and that all the fingers are properly set up. The fingers of your box and pan brake can be easily sprung if the machine is misused or improperly adjusted. Don't bend rod, wire, band iron, or spring-tempered sheets on either the cornice or the box and pan brake.

You can form your cylindrical pipe sections and other curved shapes by hand over a pipe or mandrel, but the forming can be done with greater ease and uniformity of radius with the SLIP-ROLL FORMING MACHINE (figure 291). Rolling machines

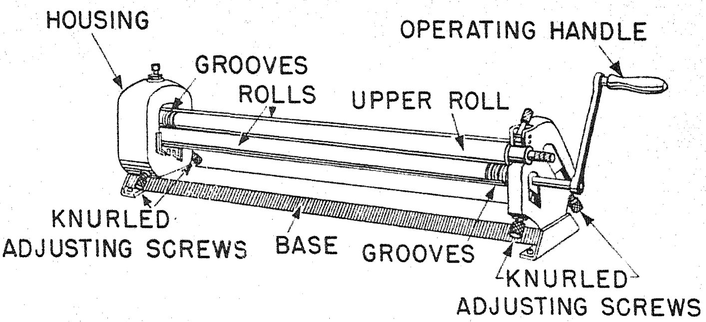

Figure 291.—Slip-roll forming machine.

are available in sizes varying from small, light-gage capacity hand-operated models to large power-operated models capable of forming cylinders of steel plates up to ½-inch in thickness. These machines operate on the same basic principle. There are adjusting screws on each end of the machine which control the vertical space between the front rolls and the position of the rear roll. To form a cylindrical object the rolls must all be parallel to each other. The front rolls grip the metal and pull it into the machine. These rolls are geared to the operating handle and must be adjusted so that just enough pressure is exerted on the sheet to enable the machine to "grab" the metal. The rear roll is an idler and is adjusted up or down to form the desired radius. Select a piece of light-gage scrap sheet metal and form a small cylinder. Proceed as follows:

1. Adjust the front rolls to "grip" the sheet you are forming.
2. Adjust the rear roll to a height (in relation to the lower front roll) that is obviously less than enough to form the desired radius of the cylinder being formed.
3. Start the sheet into the roll. As soon as the front rolls have gripped the sheet, raise the free end slightly.

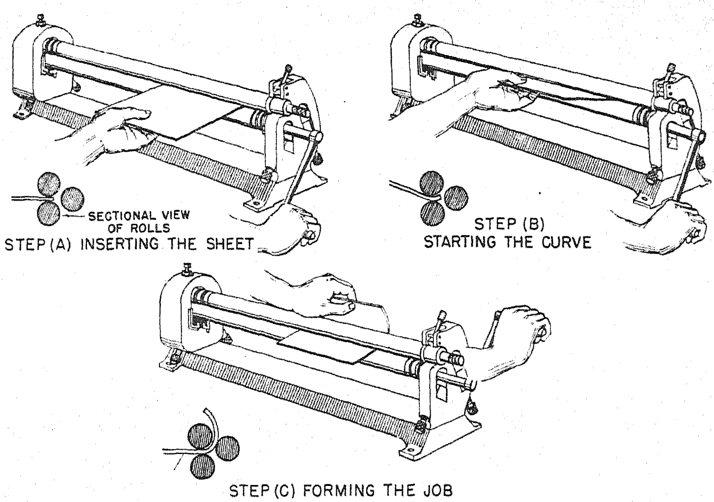

Figure 292.—Forming a cylinder.

4. Pass the entire sheet through the rolls, forming a partial curve of the cylinder.
5. Set the rear roll higher to form a shorter radius.
6. Turn the sheet, end for end, and pass it through the rolls.

Continue turning the sheet end for end, adjusting the rear rolls, and passing the sheet through the rolls until the desired radius is formed. To facilitate the removal of cylinders from the rolls, the top front roll has a releasing device by which you can release and raise one end of the roll to slip off the work. Practice and experience will enable you to adjust the rear roll for any desired radius. It is not good practice to form the cylinder in one pass, as the radius will not be uniform. You will have better results if you form the cylinder in two or more passes.

When you have to form circles of wire or rod, you'll form them in the grooved portion of the rolls. You can also roll cylinders that have a wired edge using these same grooves to form the wired portion (figure 293).

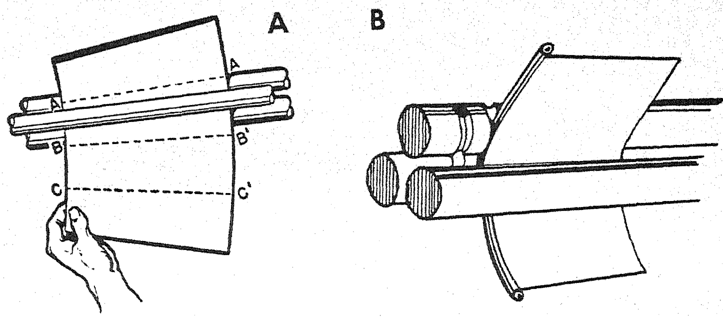

Figure 293.—(A) Rolling a conical shape (B) Rolling a wired edge.

You can roll a conical shape either by setting the back roll at an angle, or by feeding the sheet into the machine in such a manner that the element lines of the cone will pass over the rear roll in a line parallel to the rolls (see figure 293(A)). This is accomplished by forcing the edge that will form the large diameter through the rolls at a faster rate than the edge forming the small diameter.

When you form a cylinder with a grooved lock seam, you will use a combination of several machines: the brake, slip-roll, a hand groover, and a hollow mandrel stake. Lay out a cylinder and make the allowance on each edge of the layout for a grooved seam (figure 243). Then—

1. Insert the sheet in the brake and form the first bend of the lock.
2. Turn the sheet end for end, and then turn the sheet over to form the bend for the other half of the lock (similar to the sheet in figure 294).
3. Adjust the slip form rolls to form the cylinder you are to roll, and roll the cylinder to size.
4. Hook the seam together and slip the cylinder over a hollow mandrel stake.
5. Select a hand groover of the proper size. (You should use a groover that is about 1/16 inch wider than the seam.) Place the groover at one end of the seam and strike it

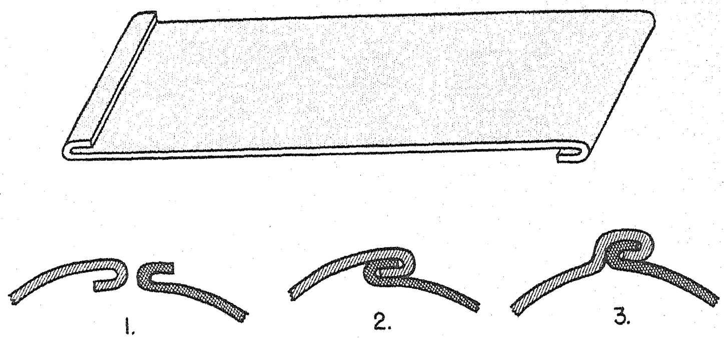

Figure 294.—Making a grooved seam.

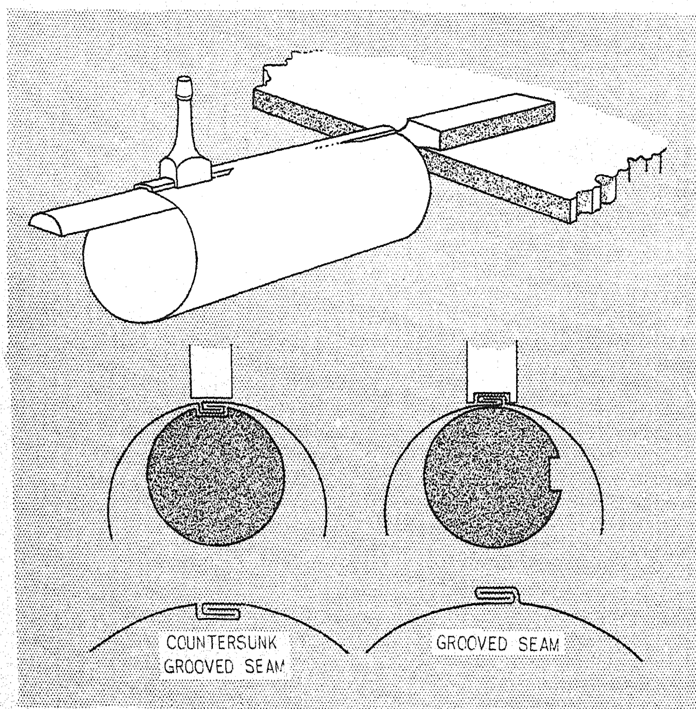

Figure 295.—Completing the seam with a hand groover.

with a hammer. Repeat the operation at the other end of the seam.

6. Complete the seam by moving the hand groover along the length of the seam and striking the head of the groover with a hammer or mallet.
7. Further lock the seam with prick punch indentations about ½-inch from the ends of the seam.

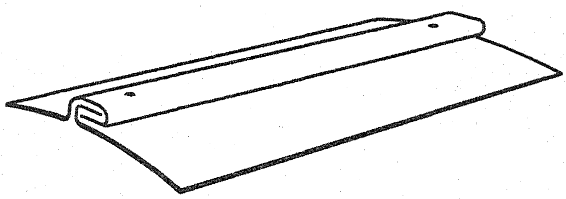

Figure 296.—A grooved seam locked with prick-punch marks.

Much of your work in forming sheet metal will be done over anvils or stakes. You may not have all of the sheet metal stakes illustrated in figure 297, but you'll probably have some of them. These stakes have a variety of shapes and are used to back up the metal when forming the many curves, angles, and seams in the forming process. The stakes are not delicate precision instruments and many of the "faces" are hardened steel; nevertheless, they demand proper care and use. Do not use them as backing when chiseling holes or notches in sheet metal. If you use them in this manner you will mar their surfaces. When not in use, they should be stowed in suitable racks. Experience and the job at hand will be your guides in the selection of the stake to help you form your metal. Some of your work will require the use of several stakes. The stake is held securely in a stake holder or stake plate (figure 297), which is anchored in the workbench. One of the tapered holes in the plate will fit the tapered shank of your stake.

You will often have use for the hand dolly illustrated in figure 298. This tool is used to buck rivets, form seams, and to straighten wrinkles and kinks in the formed metal. Hand

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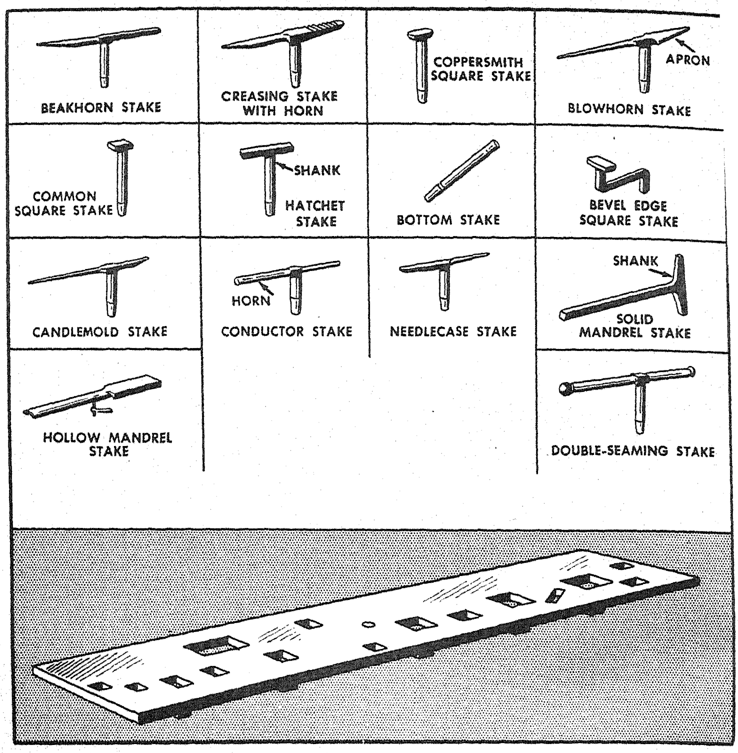


Figure 297.—Sheet metal stakes and stake hoider.

dollies have a variety of shapes and sizes, and in some cases you may have to make your own for a particular job.

Remember the cone you laid out in figure 262? If its dimensions were large you could probably form it in the slip-rolls; but if it were a small cone you'd have to form it over the apron of the blowhorn stake as illustrated in figures 299 and 300.

1. Start the bend at each end of the piece by light blows with a mallet.
2. Form the remaining portion of the cone with your hands, by working the sheet with a rolling, sliding motion over the stake.

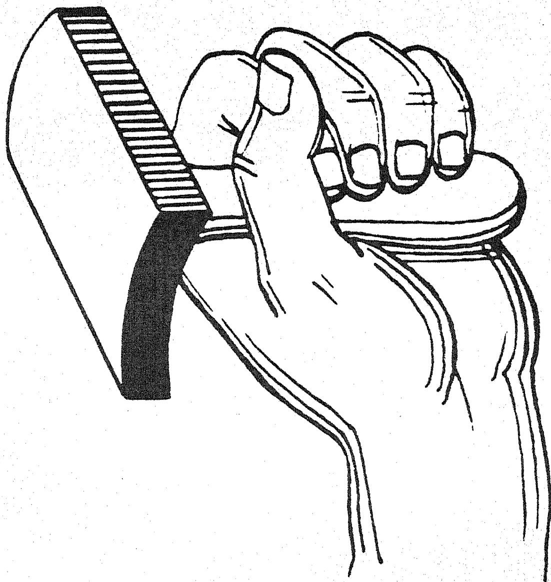


Figure 298.— Hand dolly.

Small, cylindrical shapes and small radii can be formed over the stakes (figure 300). When selecting a stake, remember that the radius of the stake must be slightly smaller than the radius of the object you are forming. Form the edges of the sheet in the manner you used on the cone (figure 299) and then finish the operation with your hands. If the material you are forming is of a gage heavier than you can readily work with your hands, you'll have to form the piece over the stake, using a mallet to shape the sheet.

Many of your jobs will require a bail (that's the metal-trade's name for a wire handle). You could make this bail, or handle, in a vise, but you can do the job a lot faster and better by using a creasing stake as illustrated in figure 301. The bail is attached to small ears, or tabs, which are in turn secured to the bucket or container. To form the bail end—

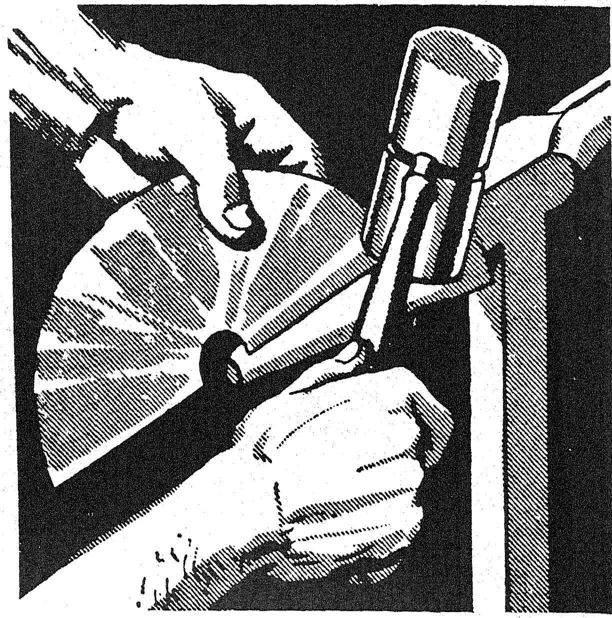


Figure 299.—Forming a cone on a blowhorn stake.

1. Select the correct groove for the size of wire from which the bail is to be made. Extend the wire about ¼-inch over the edge of the stake and bend it down 45° by striking it on the end with a tinner's hammer.
2. Slide the wire the required distance and make a 90° bend. This distance will be determined by the size of the ear, or tab, you plan to use.
3. Revolve the wire so that the bent end points up. Slip on the ear and, with inward blows, strike the end of the wire to form the loop around the ear (see figure 301).
4. Repeat the operation on the other end of the wire. You can form the curved portion of the bail by hand, or by rolling to the desired radius in the slip-roll machine.

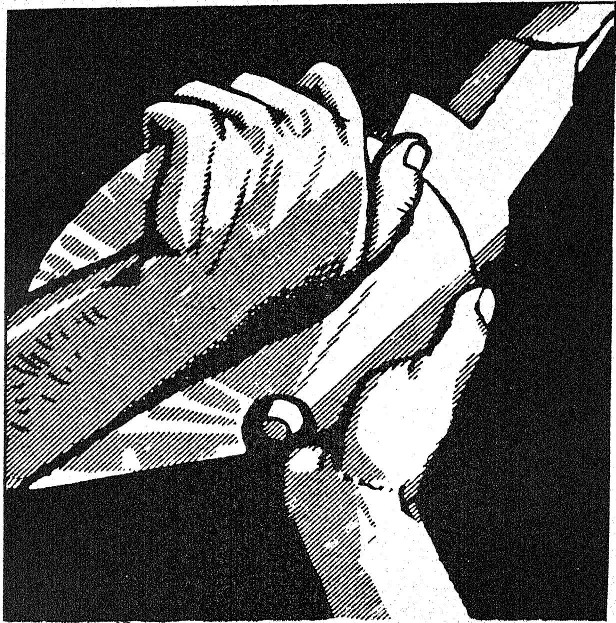


Figure 300. — Forming over a stake by hand.

Small pans are difficult to form completely in the cornice brake without doing a lot of extra mashing and beating on the metal. A much smoother job can be turned out by "braking" the longest sides in the brake and forming the ends over a square stake. The ends can also be formed as illustrated in figure 302. Cut a block of wood equal to the width of the pan you are forming, then—

1. Clamp the metal and the block of wood to the workbench with a C-clamp.
2. Bend the end up with your hands and finish the bend with a mallet. (The bend can be started in the brake if desired.)
3. Repeat the procedure for the other end.

Make use of the stakes you have available every chance you get. The more experience you have with them the more uses you will find for them. Some additional suggested uses for stakes are illustrated in figure 303.

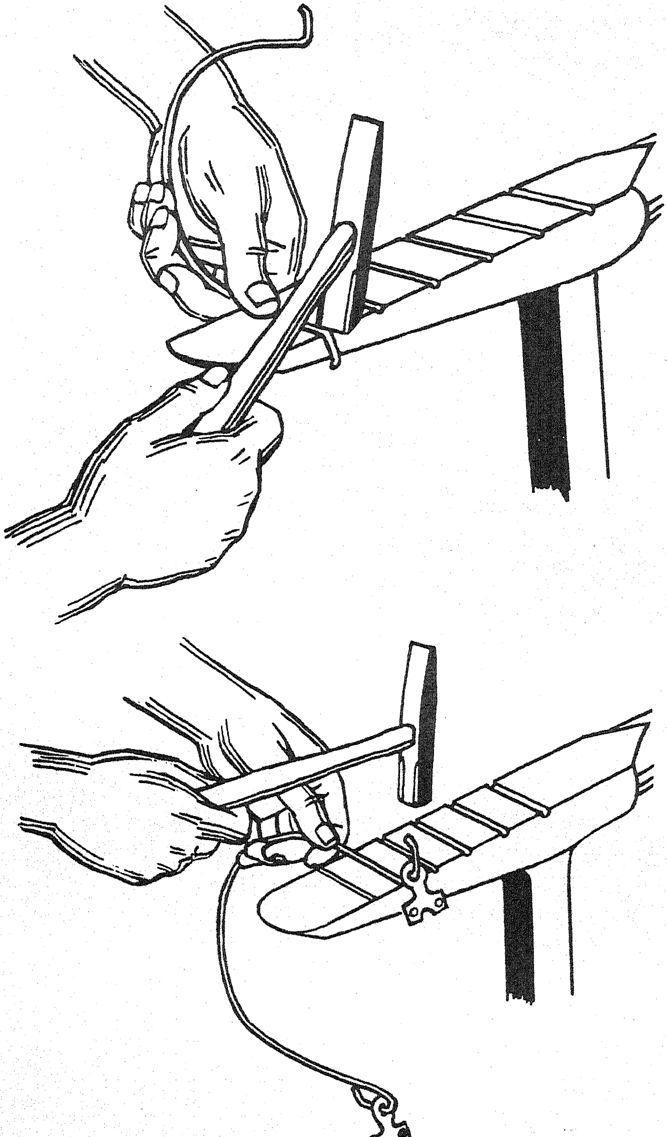


Figure 301.—Forming a bail.

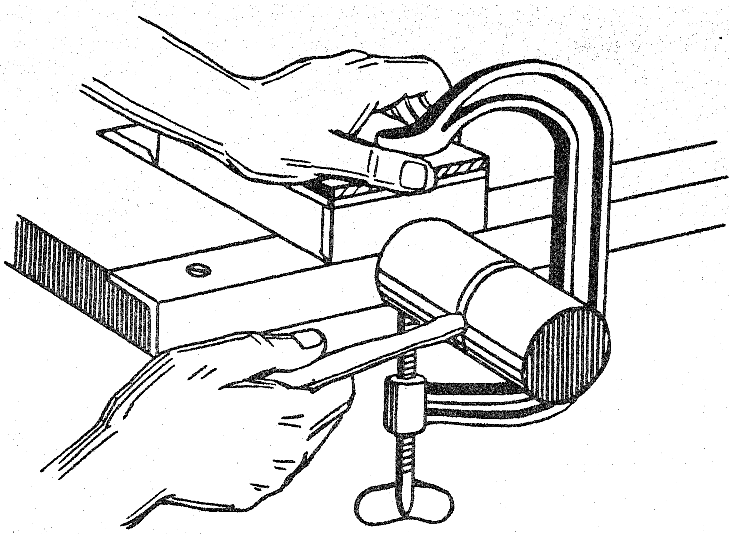


Figure 302.— Forming over a block of wood.

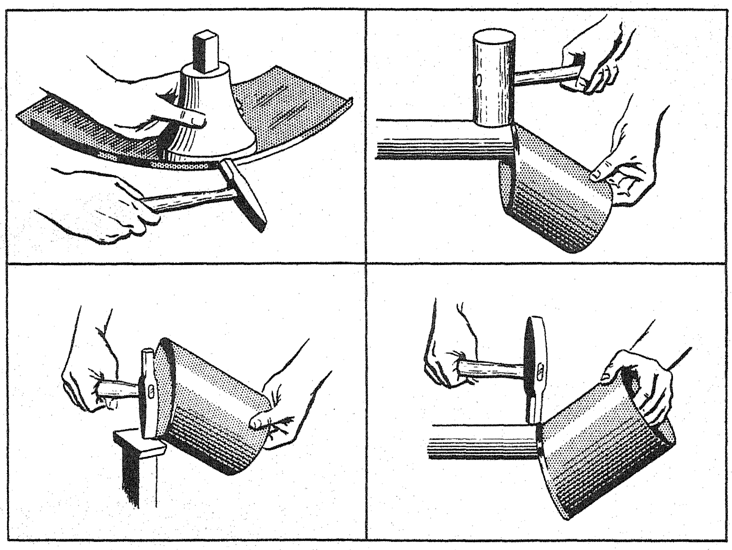


Figure 303.— Additional uses of stakes.

One of your many qualifications for Metalsmith is the forming of a copper ball float. This float is used on the flushometer that regulates the flow of water into the water closet of some "heads." The process used in making the ball or float is known as bumping or raising. Figure 304 illustrates the manner in which one-half of the float is raised. You can use either a block of hardwood that has had a depression machined in it, or you can use a block of lead in which you have formed a depression with the bumping hammer. Whether you use a block of wood, a lead block, or a section of pipe having the desired diameter, the operation is about the same.

1. Select a piece of annealed copper and cut a circular blank large enough to make one-half of the float.
2. Hold the blank in position over the raising block in your left hand. Start forming the radius by working around the outside edge of the blank with the bumping hammer (figure 304).

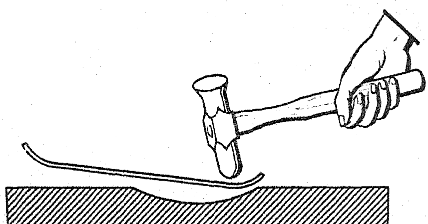


Figure 304.— Raising or bumping a copper ball.

3. Rotate the blank slightly after each blow of the hammer.
4. When you have made one complete revolution on the outside edge of the blank, continue forming the radius by rotating the blank and working each complete rotation of bumps toward the center, until the desired radius is formed. It may be necessary to anneal the blank frequently before the final shape is attained. When your blank becomes difficult to work and has a "ring" to it, it is time to anneal the piece.

Another method of raising is illustrated in figure 305. In this method you use a mallet and a coppersmith's round head

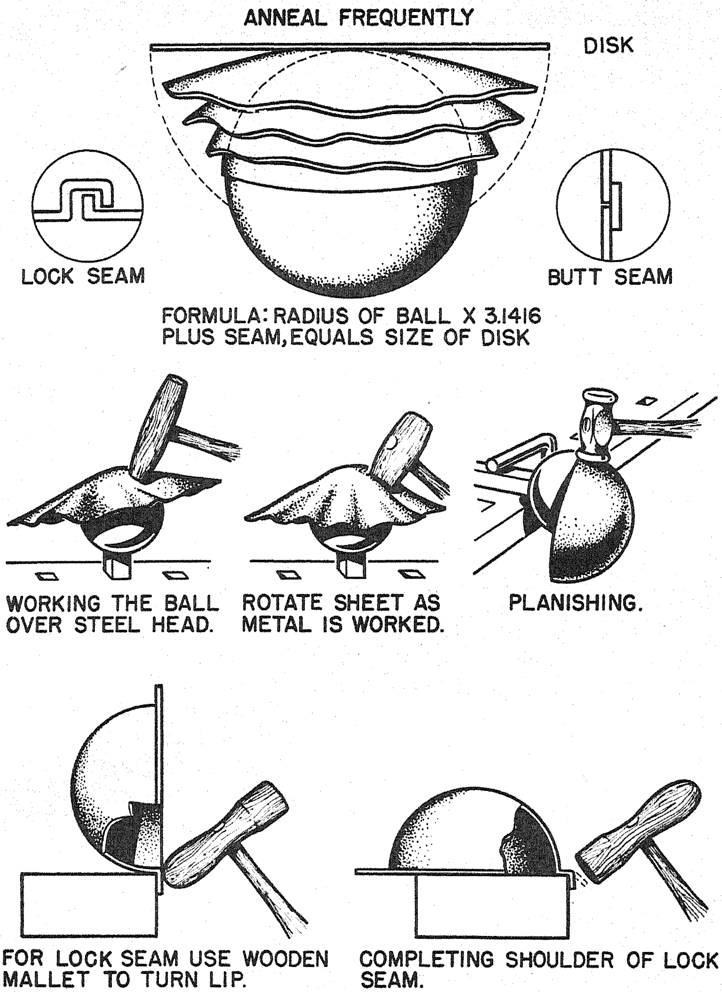


Figure 305.—Bumping over a stake.

or ball stake. Hold the blank at an angle on the stake. Working from the outside edge, rotate the blank in a manner similar to the preceding method. Form the blank into shape by striking with a wooden mallet. Final forming of the half-ball can

be accomplished by holding the section in both hands, bumping and smoothing the radius over the head of the stake.

Be careful if you make a prick-punch mark on the blank when laying out the work. The metal may be stretched considerably in the forming process and the punch mark is apt to develop into a pinhole.

The two halves of the ball are made so that the edges just lap together and the seam is completed by soldering or silver brazing.

You'll find that your bench vise is one of your most useful tools. You will bend scrap iron and short sections of metal in it. You will often use the vise to hold your metal firmly in place while you saw out sections with the hacksaw, or to chisel thin sections as illustrated in figure 306. When cutting out sections in this manner, be sure to hold the cutting edge of the chisel at an angle to the work. Don't watch the head of the

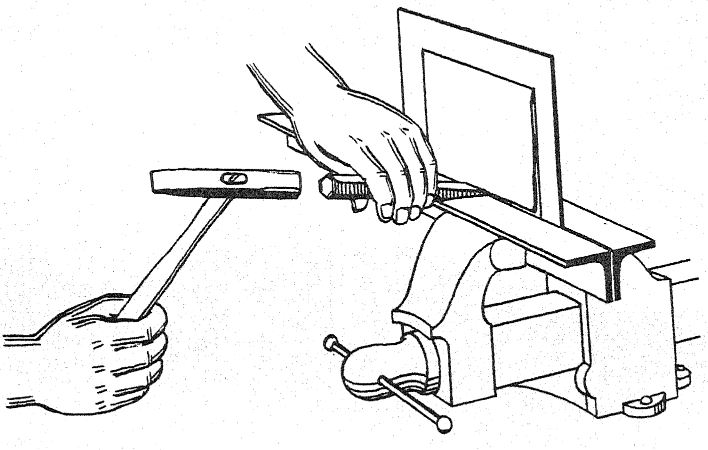


Figure 306.—Cutting light metal in a vise.

chisel. Watch the cutting edge when you are striking the chisel with the hammer. CAUTION: Be sure that the head of the chisel is not mushroomed (spread out), or a piece may break off and fly with the speed of a bullet. Eyes have been knocked out because someone used a chisel with a mushroomed head.

Not all, but a large majority of your seams in sheet metal will be riveted. Rivets are available in a variety of sizes and heads. The tinner's rivet is the type with which you will most often come in contact. It will vary in size from the 8-ounce to the 16-pound rivet. This designation is the weight of 1,000 rivets (1,000 of the smallest size weighs 8 ounces). As the weight per 1,000 rivets increases, the diameter and length of the

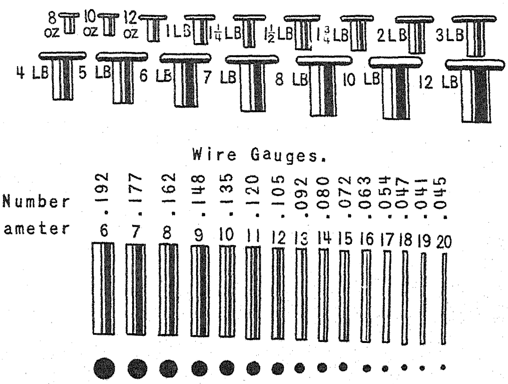


Figure 307.—Tinner's rivets.

rivet increase. The 8-ounce rivet has a diameter of 0.089 inch and is 5/32 inch long, and the 12-pound rivet has a diameter of 0.259 inch and is ½ inch long. For special jobs that require fastening several thicknesses of metal together you'll use a rivet that has an extra long shank but the same diameter as the rivet you would normally use. Select the proper rivet-size for the gage of metal you intend to fasten. The following table will be of help in selecting the proper rivet:

TABLE I

GAGE OF METAL	SIZE OF RIVET	GAGE OF METAL	SIZE OF RIVET
26	1 lb.	20	3 lb.
22	2 lb.	18	3½ lb.
42	2½ lb.	16	4 lb.

You will determine the rivet spacing from the drawing or blueprint. If the spacing is not indicated, the type of seam will indicate whether the rivets should be spaced close together or far apart. A job that has to be watertight will have many more rivets per inch than a job that does not. Whether the spacing is close or far apart, be sure that you allow a distance two-and-a-half times the diameter of the rivet from the edge of the sheet when locating the center line for the rivet hole.

When you have determined the rivet size and marked the location of the centers for the rivet holes, your next step is to pierce the holes. You can do this either by drilling or by punching. If the location of your holes is near the edge of the sheet, the hand punch illustrated in figure 308 will serve you to good advantage. Rivets are not always located near the edge of the sheet, and if they are not you'll have to pierce the holes with another tool. You may have a power-operated or manually operated hand punch that has a deep enough throat to do the job. But if you haven't, you can always drill the hole with a breast drill. Whether you pierce the hole with a drill or punch, remember that you have to make the hole a little larger than the diameter of the rivet. (This is known as clearance.)

There are a number of hand punches manufactured, and construction of the individual punch you have may be different from the one illustrated in figure 308. These punches are handy tools around the sheet metal shop. The punches and dies have a range of sizes and are easily changed. Be sure that you do not get the punches and dies mixed up. Don't change the punch size without changing the die. Make sure the punch and die are mates. If you force a punch into a smaller-sized die you'll break one, if not both, of the parts. Keep the tool well lubricated to insure ease of working.

The punch usually has a gage attached to it as shown in figure 308. The gage consists of a guide mark and an adjustable scale. The scale graduation opposite the guide mark indicates the depth of the throat in inches; that is, how far from the edge of the sheet metal the center of the hole will be punched when the end of the scale is against the edge of the sheet.

The gage is not often used, however, because generally you'll

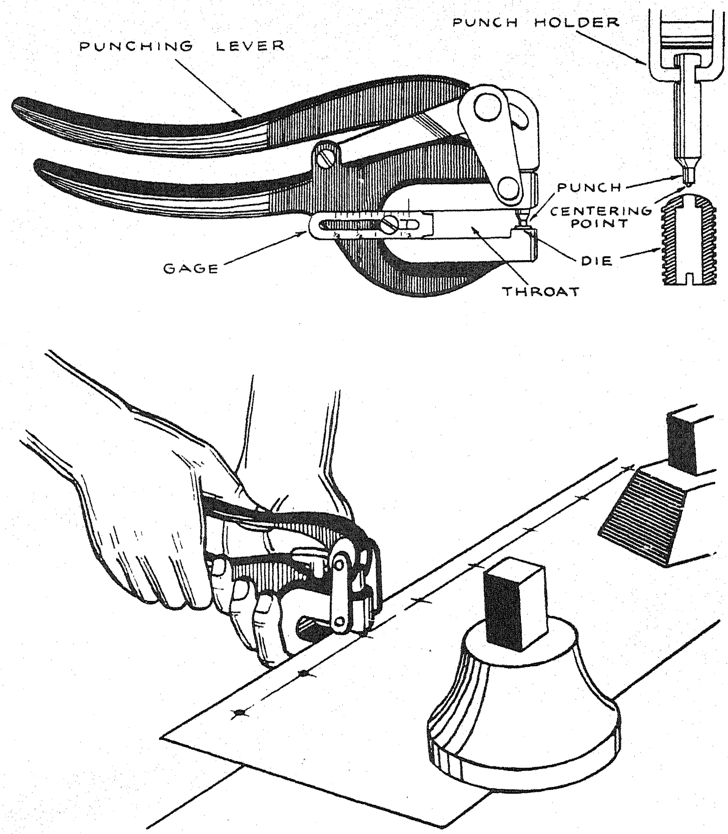


Figure 308.—The hand punch.

first use a center punch to mark the position of the hole to be punched in the sheet metal. You can easily "feel" this punch mark with the centering point on the hand punch. Figure 308 illustrates the hand punch in use. Don't use the punch beyond its rated capacity.

You'll have a lot of use for your breast drill even if you have an assortment of electric and air-driven power drills available. There'll be times when you have only a few holes to drill on a job away from the shop. Rather than run a long power lead to

the job, it will save you time and trouble to carry the breast drill, illustrated in figure 309, right to the job. The drill chuck is adjustable to receive and hold straight shank drill bits from 1/64 to ¼ inch in diameter. You just select the bit of the proper size, secure it in the chuck, place the point of the drill bit in the center punch mark, and turn the handle. Be sure to keep the drill at right angles to the metal.

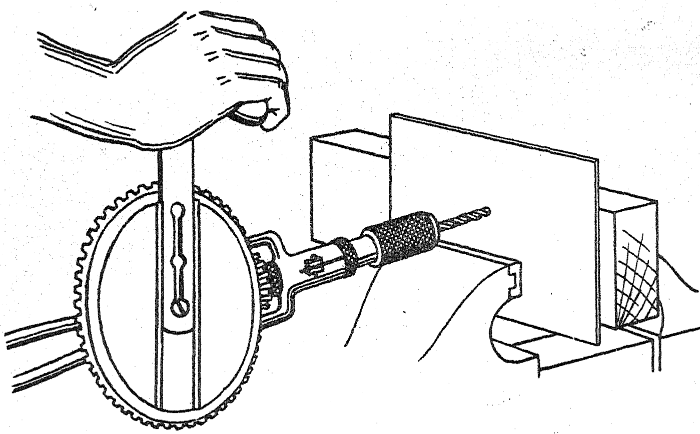


Figure 309.—A breast drill in use.

You'll use a rivet set to DRAW the metal parts together and HEAD the rivet. Select two pieces of scrap sheet metal. From the table, determine the correct rivet for the gage of metal you have at hand. Lay out and punch the holes, remembering that the holes must be slightly larger than the diameter of the rivet. Then—

1. Select a rivet set having a hole slightly larger than the rivet diameter.
2. Insert the rivets in the holes and rest the sheets to be joined on a stake or solid bench top with the rivet heads against the stake or bench top.
3. Draw the sheets together by placing the deep hole of the

rivet set over the rivet and striking the head of the set with a riveting hammer. Use a light-weight riveting hammer for small rivets and progressively heavier hammers for heavier rivets (figure 310).

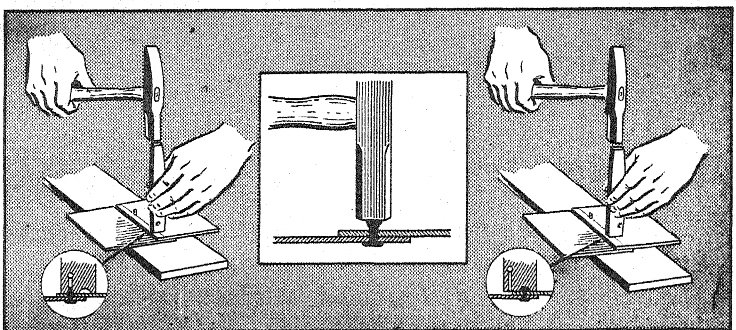


Figure 310.— Drawing, upsetting, and heading rivets.

4. When the sheets are properly drawn together, remove the set and strike the end of the rivet a blow with the riveting hammer to upset the end of the rivet. Don't strike too hard a blow, as it will distort the metal around the hole (figure 310).
5. Place the dished portion (the heading die) of the rivet set over the rivet and form the head. One or two blows struck on the head of the set with the hammer is sufficient to form the head (figure 310).

A correctly drawn, upset, and headed rivet is illustrated in figure 311. Avoid the troubles illustrated in the lower half of the illustration.

Remember that it is not necessary to use all the force within your power to do a good sheet-metal riveting job. Just strike hard enough to do the job. When you are riveting a job as illustrated in figure 311, the "bucking" has to be done with a hand dolly. If you are on the heading side of the job, striking blows with too much force will needlessly jar your "bucker."

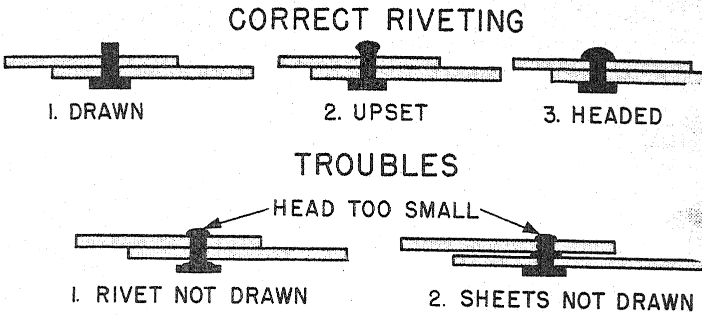


Figure 311.— Correct and incorrect riveting.

Besides that, it will distort and mark the metal, spoiling the appearance if not the strength of the seam.

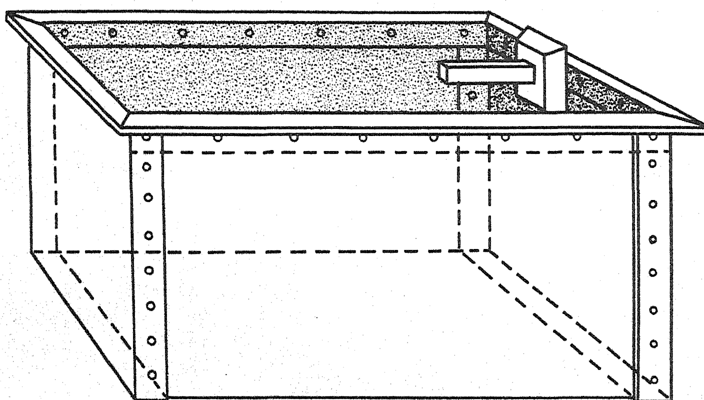


Figure 312.— Bucking rivets with a hand dolly.

Look at your rivet set. Notice the hole that goes thr[illegible] the flat side? On very thin sheets you can set the rivet at the desired location, back it up securely, and force the rivet through the metal by placing this hole over the rivet on the opposite side of the metal and striking the set with the riv[illegible] hammer.

sure that the burr hole in the rivet set is directly over the rivet or you'll not force the rivet through without undue distortion of the metal and damage to the head of the rivet. Don't try this method with the heavier-gage metal.

hen you have a seam to rivet on a cylindrical structure, u can use the hollow mandrel stake or other suitable bar as acking to buck your rivets. On these seams, insert rivets in end holes, slip the piece over the stake and—

1. With the rivet set, draw the seam together.
2. Strike the rivets with the riveting hammer to upset the rivets enough to hold the structure together.
3. Insert the center rivet. Draw, upset, and head this rivet.

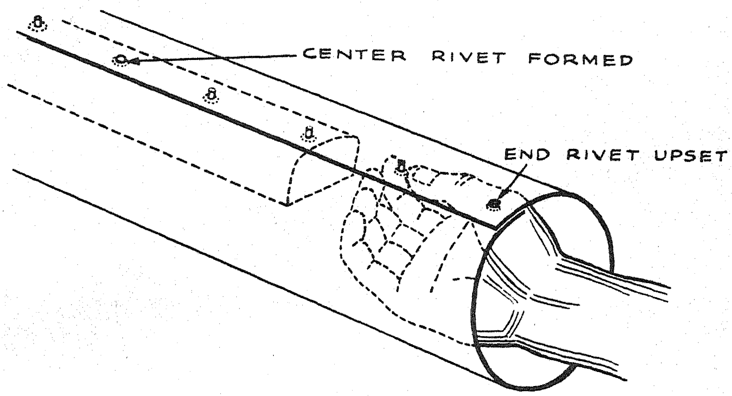


Figure 313.—Riveting a cylindrical section.

4. Complete the seam by riveting from the center to the one end and then to the other end completely drawing, upsetting, and heading each rivet as you work along the seam. If you have a little trouble lining up the holes to receive the rivet, you can "fair" them up with a small drift ... r your scriber.

Wired edges are often used to form the edges of trays, air supply terminals, buckets, cans, and funnels. These edges are made by wrapping the metal edge around a wire (see figure 314). For thin metal, the allowance for a wire edge is two-and-a-half times the diameter of the wire. It is slightly more for

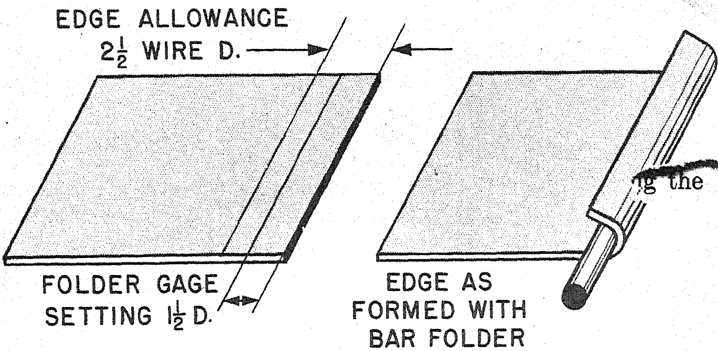


Figure 314.— Planning the wired edge.

heavy gages. These edges are strong and smooth when properly made. The metal should always fit tightly around and cover the wire completely. The wired edges may be finished with wire rolls if you have them available (see figure 321), or with the setting hammer.

An edge for wiring may be turned with the turning rolls or the brake. You can wire the edge of a cylinder before th cylinder is rolled to shape. After the edge is turned, it is form around the wire as shown in figure 315. The pliers are used to hold the wire tight against the metal and to protect your hands.

When you are wiring the edge of a rectangular box or tray, you can form the wire in a vise and then form the turned edge over the wire with a mallet or with the wiring rolls. F illustrates this procedure.

If you're working in a large shop you'll have yo rotary machine for burring, turning, wiring, beading, setting down, grooving, and crimping. Smaller shops will

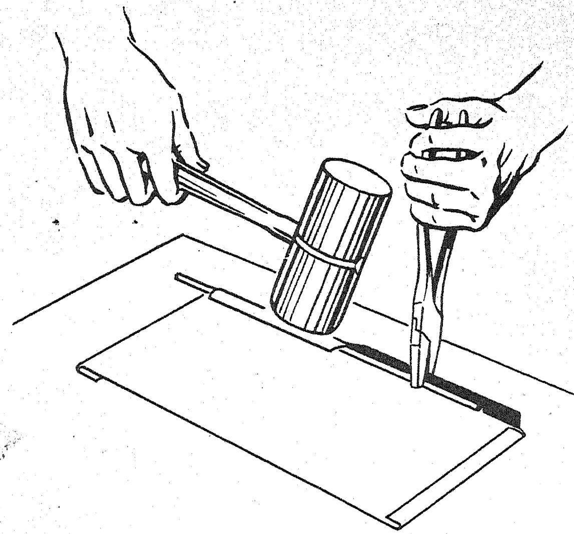


Figure 315.—Wiring a straight edge before forming.

machines. Some of them will be of the combination variety with one head and several sets of rolls. A combination rotary head, with burring rolls mounted, is pictured in figure 317. This rotary head will take sets of rolls for burring, turning, wiring, and elbow edging. The rolls are secured to the shafts by round nuts which screw flush with the outside of the rolls. Don't be surprised if some of these nuts have left-hand threads. A special face-pin spanner wrench is used on these nuts.

The burring rolls are used to turn an edge at right angles to form burrs (narrow flanges) for seams or hems. Ordinarily, you'll have two sets of burring rolls, one set for narrow burrs and one for wide burrs. A typical use is for burring the disks which form the bottoms of some buckets and tanks.

It takes a little patience and some practice to turn out a perfect burr like the one the workman in figure 318 is cranking out. Here's how you do it:

Adjust and aline the rolls so that the inside edge of the top roll fits over the shoulder of the bottom roll. Make the clearance equal to the thickness of the metal. This is

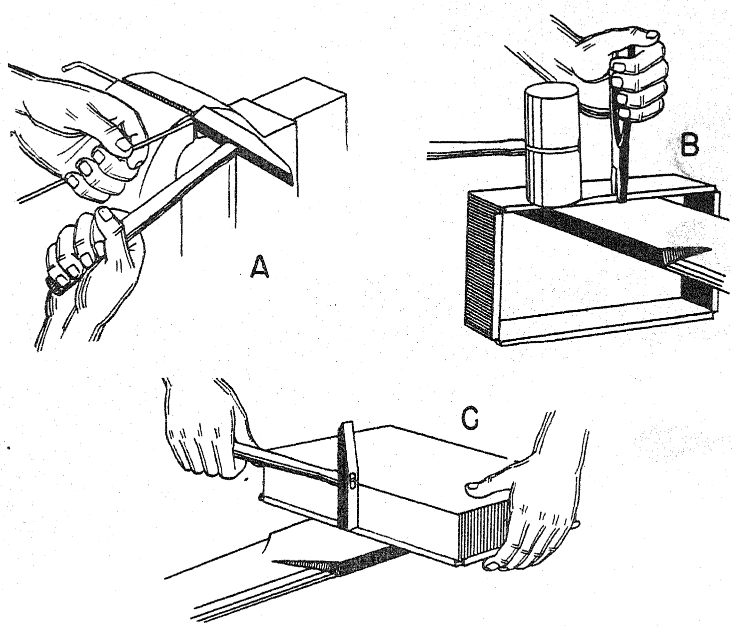


Figure 316. — Wiring a box.

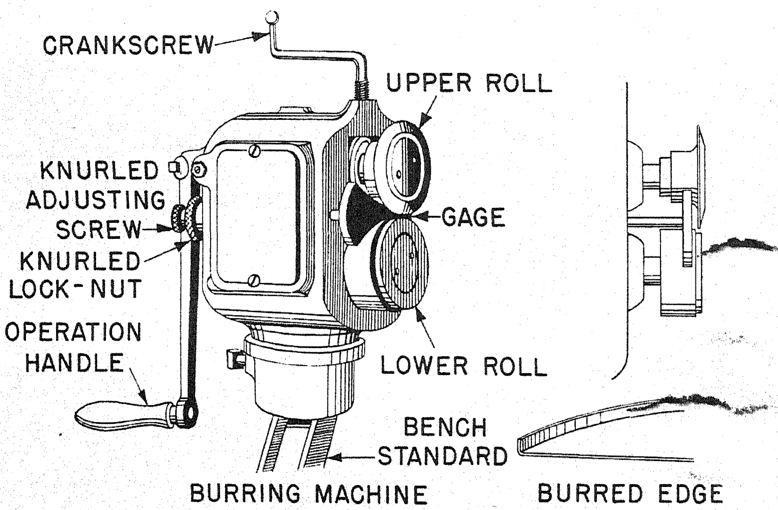


Figure 317. — Rotary machine with burring rolls.

important—less clearance will cause the top roll to act as a shear and damage your stock.

2. Set the gage to turn up the proper amount of metal. This is usually from $\frac{1}{8}$ to $\frac{3}{16}$ inch.
3. Place the disk as shown in figure 318A and move the top roll down until it grips the stock and creases it slightly.
4. Crank the handle. Keep the edge of the disk tight against the gage. Allow the disk to revolve as you crank.

   The first revolution should be fairly slow so you can get the burr accurately established. After the first revolution of the disk, disregard the gage and follow the crease, increasing the top roll pressure and turning as before. Raise the disk slightly after each revolution. After the first round you can crank faster and faster—especially

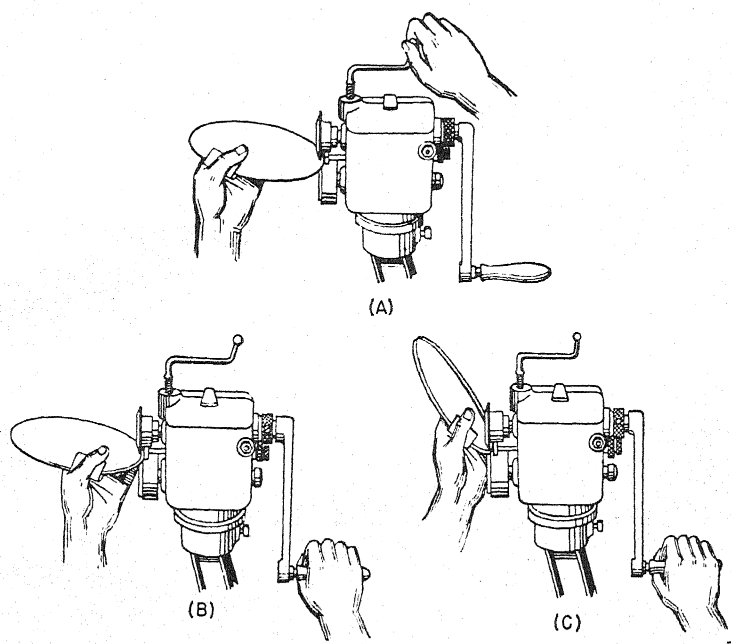


Figure 318.—Burring a disk.

when you've burred several disks and begun to get the hang of it.

The turning rolls are used to form rounded flanges—similar to burred edges but having radii. These rolls are used to form edges for wiring. Several sets of rolls like those in figure 319 are usually provided.

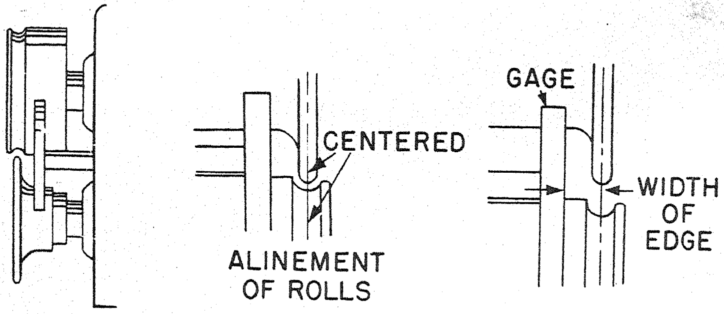


Figure 319.—Turning rolls.

The turning machine does a good job if you keep the rolls alined, set the gage properly, and hold the edge of your metal firmly against the gage during the first revolution.

Elbow edging rolls are similar to turning rolls but have V-grooves in the lower rolls and matching upper rolls. Figure 320 illustrates one piece of an elbow being edged. Notice that one

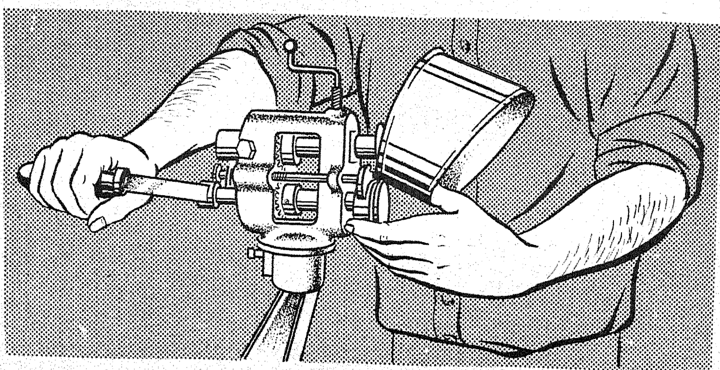


Figure 320.—Elbow edging.

edge is turned in and the other turned out. The various pieces of the elbow are assembled together by interlocking the edges.

Wiring rolls are used to form or shape the metal around a wire. The edge of the metal is first turned on the brake or rotary turning rolls. The job is completed with the wiring rolls. Parts *B* and *C* of figure 321 show these two steps. Wiring rolls may be used on either straight or curved edges.

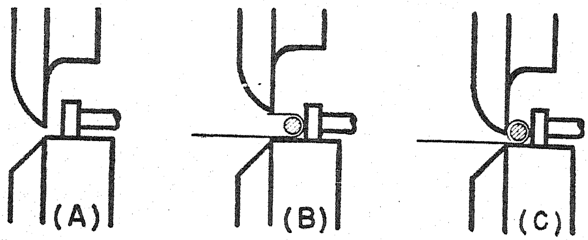


Figure 321.— Wiring an edge.

Setting-down machines are used to close single seams. They are separate one-job machines; that is, they can be used only

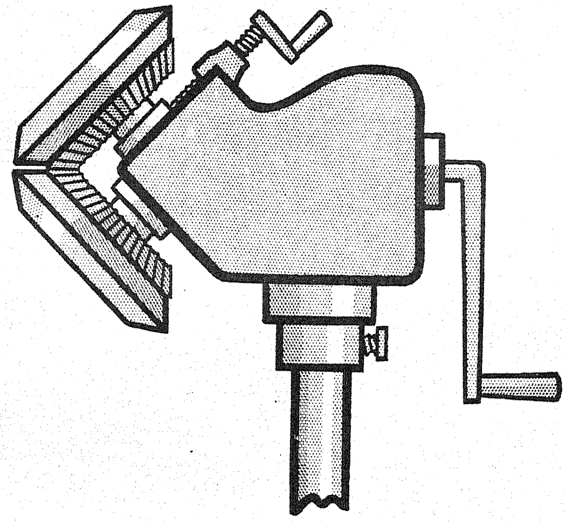


Figure 322.— Setting-down machine.

for setting down or closing seams. Their beveled jaws grip the seam and mash it down to make it tight and smooth.

Beading may be done in an emergency with the turning rolls of the combination rotary machine discussed above. The deep-throat beading machine, however, is especially designed for beading. One is shown in figure 323. Several types of beading rolls may be used with this machine.

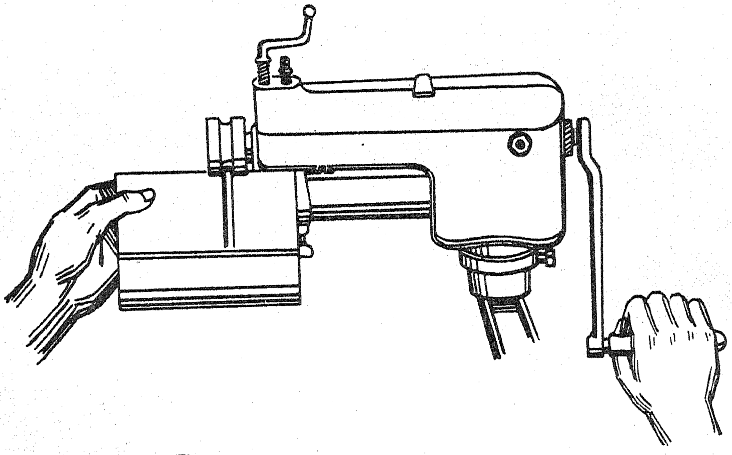


Figure 323.—Deep-throat beading machine.

You will need to take several revolutions to form a bead, thus avoiding severe stresses and possible cracks. Start beading next to the seam and stop just before the seam is reached. NEVER ALLOW A SEAM TO PASS THROUGH THE ROLLS. If the thick seam goes through the rolls, it will spring the machine and weaken the seam.

Crimping machines (figure 324) are used to shrink (by corrugation) the ends of metal cylinders so they can be fitted, as stovepipes are, into other cylinders of the same diameter. Some of the crimping machines also carry beading rolls next to the crimping rolls, as shown in the lower drawing in figure 324. The bead reinforces the cylinder and prevents it from slipping too far into the other cylinder.

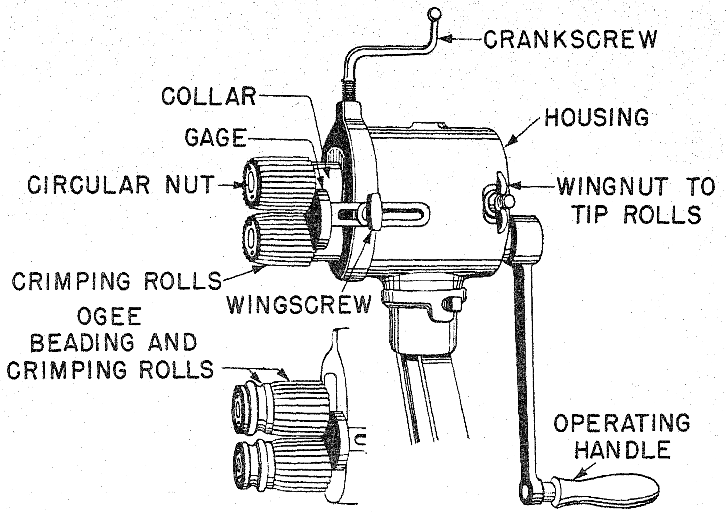


Figure 324.— Crimping machine—combination crimping and beading rolls.

For jobs with riveted or grooved seams, start the crimp near the seam and run it around until it just comes back to the seam. Never crimp over a seam—it will damage the rolls and spring the shafts. Keep the edge of the cylinder against the gage and you'll get a neat job.

Always double-check your machine setup by doing a practice job on a piece of scrap stock of the same material that you are

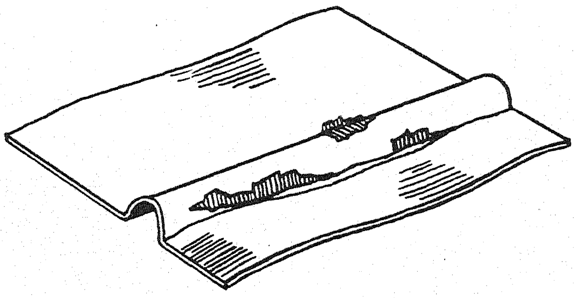


Figure 325.— Results of incorrect beading.

using for the job. This will save you a lot of time and trouble and save Uncle Sam a lot of sheet metal.

Take it easy when you form galvanized sheets. If you're too rough with this material, the zinc coating will flake and chip off, leaving the bare base metal an easy mark for corrosion. Figure 325 illustrates the result of incorrect beading.

PLAIN DOUBLE SEAMS are the kind often used on the bottoms of cylindrical containers—buckets, cans, trays, and boxes. These seams are also used in the construction of air ducts. Figure 326 shows a double seam in four stages of construction. The clearance indicated by the arrow in step three is important. It should be slightly greater than the metal thickness. If you don't have enough clearance the seam will be forced apart and the wall of the object will be forced out of shape.

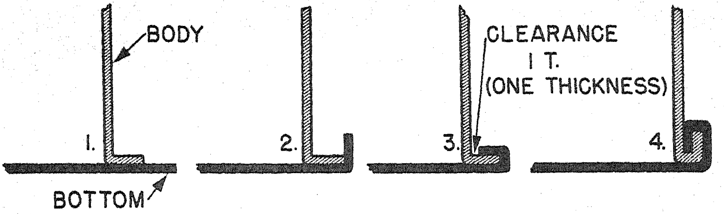


Figure 326.—The double seam.

Burred disks, known as snap bottoms, are used for the bottoms of cylindrical and conical containers. The necessary

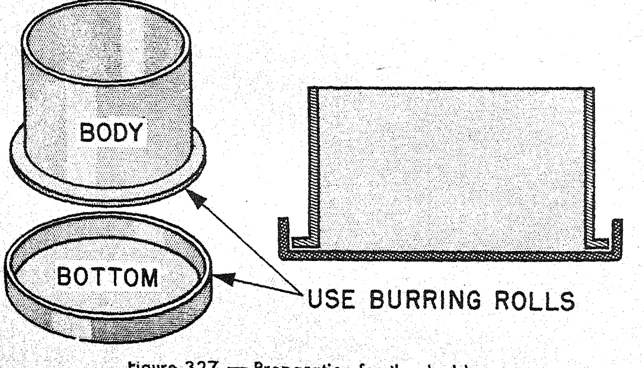


Figure 327—Preparation for the double seam.

machine preparation for a disk and cylinder is shown in figure 327.

After the cylinder and bottom are snapped together, the burred edge of the bottom is turned over the burred edge of the cylinder (figure 328) and "set down" with the setting-down machine *B*. After the seam is smoothed and flattened, it may be partially closed by turning it upward toward the top of the cylinder over a stake *C* and finished by pounding the seam over with a mallet *D* and *E*. The seam is then smoothed and straightened.

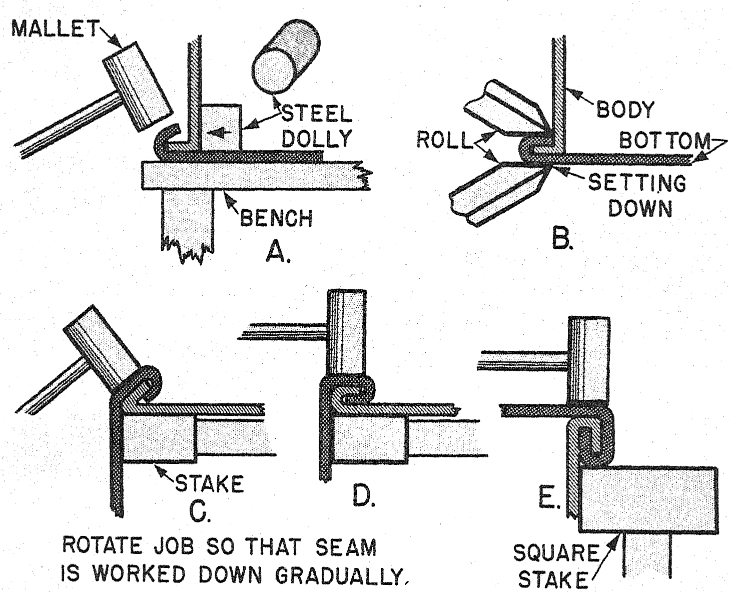


Figure 328. — Finishing the double seam of a cylinder bottom.

On some jobs the insert double seam (figure 329) is used instead of the plain seam. You can see why it's better for containers such as buckets and tanks. One big advantage of this seam is that it can be used on long cylinders. The seam can be formed from the outside by putting only the end of the cylinder over the stake.

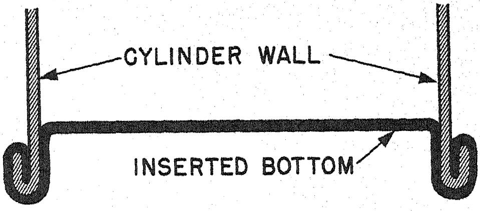


Figure 329.—Insert double seam.

When you have a bit of spare time, familiarize yourself with the stakes, tools, and rotary machines that you have in your shop. Use scrap bits of metal and practice turning edges and burrs for wiring and seaming. If you don't have the machines illustrated, you'll have to figure out a new method of doing the job with the tools you have available. Your own ingenuity and inventiveness will be the only limit to the scope of work you can perform with a hammer, chisel, screw driver, and a few other odds and ends floating around the shop.

As the Metalsmith of a small ship, most of your work will be in the nature of patching and upkeep. Here again your resourcefulness and ingenuity will pay you big dividends. You may have to replace a flange or a section of ventilation line; you may have to patch a tank or garbage pail; you may have to make an ash tray. Some of your patching will be done by welding, soldering, or riveting. On other jobs you may not be able to use any of these methods because of the particular circumstances. In that case you may use sheet metal screws or machine screws to secure the structure or patch in position. Review your basic course, *Use of Tools*, NavPers 10623, for a description of sheet metal and machine screws.

BUILD A LOCKER

Not long after you have become a striker in the metal shop you'll want to try your skill on a job for yourself. Maybe you'll want to build a tool box to stow the hand tools you have begun to accumulate. Or perhaps you have located a vacant spot in the shop to install a small personal locker. (There won't be

much unused space on ships that have been in commission for a while.) If your division officer or CPO gives you permission and allots you the metal, you'll have to build the locker or tool box yourself on your own time after working hours.

Assuming that you have found a vacant spot and have obtained permission to install a locker in that spot, the next thing for you to do is to plan your work. You'll have to ascertain, by measurement, the over-all dimensions of the locker—the outside dimensions. These measurements will determine the size of your layout. Remember that you will have to make allowances for the thickness of your metal. After you have determined the size of your locker and the thickness of the metal you'll use, think about and plan these points:

1. *Method of seaming.*—Welded? Riveted? Double seamed or Pittsburgh lock seamed?
2. *Type of door.*—Are you going to hang a piece of 1/8-inch sheet metal on the front of your locker, or are you going to lay out a flush-type door? You'll want the flush door on your locker and you'll have to plan the layout to match the door.
3. *Hardware.*—Hidden or exposed hinges? Barrel bolt, hasp and staple, or cabinet locks?
4. *Shelves.*—How many and where?
5. *Notches.*—Are they necessary?

Figure 330 is a sketch of a locker that has one riveted shelf. The locker is assembled with Pittsburgh lock seams and rivets. The door is set into the front of the locker to make a flush front, and is swung on exposed hinges. The securing device is a hasp and staple.

After you have laid out and constructed a number of lockers, you will probably begin by squaring up your sheet and then start laying out directly from the lower edge of your metal. If you can start out that way without getting lost, hop to it. Otherwise, it may be a good idea for you to lay out the main body of the locker and then add to it for your seams and door jamb. You know how to make your layout for the Pittsburgh seam and a riveted seam. You have two of these seams to lay

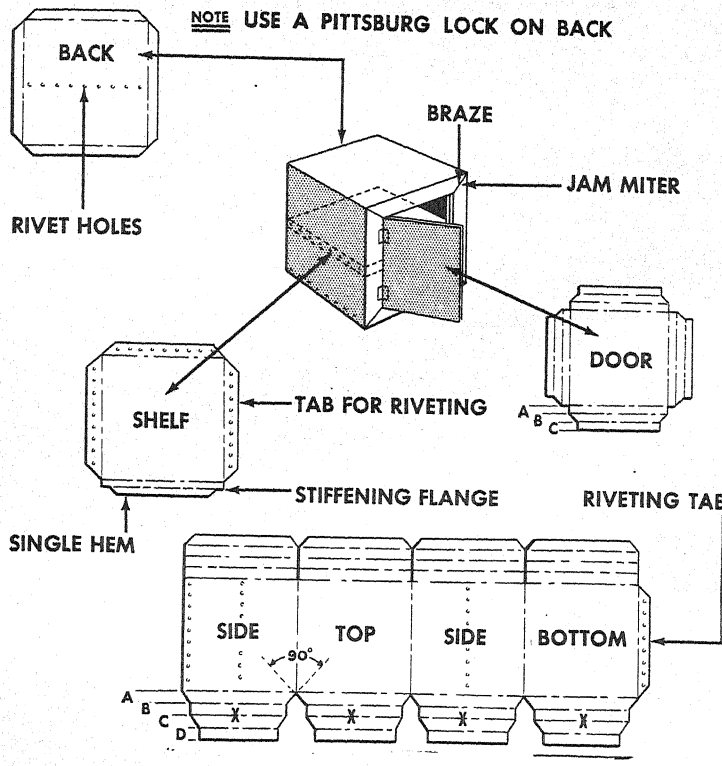


Figure 330.—Sketch of a locker.

out, one to seam the main body of the locker and the other to seam the back. If you are not sure of the Pittsburgh and riveted seam layout, check the sections covering those layouts in the preceding chapter.

The layout for the door jamb will be determined by the following factors:

1. The size of the door you want in relation to the size of the locker. The difference will control *A* in the sketch.
2. The thickness of the door. This will control the dimensions of *B*.
3. The width of the stop *C* (3/8 to ½ inch is sufficient).
4. The allowance for the single hem *D* will be slightly less than the width of the stop.

The next step is the layout for notches. For the Pittsburgh seam the notches are square, as indicated. The notches of the door jamb are a combination of notches. *A* is laid out at 45° at the base line, *B* at 90°, *C* at 45°, and *D* at 90° to the base line.

Now lay out your rivet holes. One set will be for the seam and the other to fasten the shelf. The sketch indicates only one shelf, but you can put in as many as you like. Be very careful when you lay out these punch marks for rivet locations so that the holes will be alined when you begin assembling.

Lay out the back and the shelf or shelves, marking and spacing the rivet holes in the same way you did on the main body of the locker. Be sure to lay out a stiffening flange on the front of your shelf so that it can support the weight you put on it.

Trim the waste material from the layout. Make the cuts for notches and punch or drill the rivet holes. Remember that the holes must be slightly larger than the diameter of the rivet.

You laid out a door jamb on your locker for a door of a particular size. You planned your door to have not only a certain length and width, but a specific depth as well. Now lay out your door. Remember that all of the layout lines will be on the inner side of the sheet when it is folded up. This will cause the door to "grow" slightly larger than the dimensions you lay out. This means that you will have to make allowances for this growing so that the door will fit into the jamb. Remember, too, that the door isn't supposed to be a "drive fit," but must have clearance to swing open freely. Perhaps at this stage it may seem to you that the locker could be more easily constructed if you made the door and then built the locker around it. Even if you did this, you would still have the problem of allowances. The allowance for the growth will vary with the metal. Twice the thickness of the metal in this case should take care of the problem. Experience will be your best teacher. don't be too alarmed if the first door doesn't fit. It has happened to the best of them. When this happens to you, think about your layout and determine why it doesn't fit so that you ... void the mistake on your next job.

In the sketch of the door layout, *A* is the thickness of the door, *B* the width of the flange, and *C* a single hem. After you

have laid out, trimmed, and notched your door, you are ready to form your locker to shape.

It doesn't make any difference which section of the locker you form first. The back has four 90° bends to form the flanges of the Pittsburgh seam. On the shelf, form the hem first, then the stiffening flange. The direction in which you bend the tabs for riveting the shelf in place will be determined by whether you want the flange to be turned up or down.

Form the pocket for the Pittsburgh seam on the main body of the locker and then form the jamb on the other portion of the sheet. When you bend the jamb follow this procedure:

1. Transfer the break lines of the jamb indicated by x on the sketch to the reverse side of the sheet.
2. Insert the sheet all the way in the brake, reverse side up and layout lines down.
3. Completely form the single hem.
4. Remove the sheet from the brake and invert it, layout lines up. Reinsert the sheet in the brake and form the flange for the stop C.
5. Remove the sheet again. This time, with the layout lines down, insert the sheet in the brake and form the depth of the jamb, B.
6. Slide the sheet out to the next brake line and form A.

When you have the Pittsburgh seam and the door jamb formed, break up the sides, top, and bottom of your locker by starting with the sheet all the way in the brake. Form the tab for riveting first, then slide the sheet out to the next brake line to form the bottom. Form the side, top, and second side in the same manner.

Form the door by making the single hem all the way around C. Then form flanges B and A on each section of the door.

Assemble your locker by riveting the side seam and putting in the back with the Pittsburgh seam. After all your seaming is finished and you have your shelves installed, the next thing to do is to braze the jamb miters at the front of your locker. Why braze rather than weld? There are several good reasons. First, the heat necessary for brazing is not as great as that needed for welding. Therefore, there is less warpage in the process,

and the protective coating of zinc on galvanized sheets is not completely burned off, exposing bare metal. Second, the bronze filler metal used in the brazing process flows over the edges adjacent to the joint, and gives the joint more resistance to rust and corrosion. In the welded joint the filler metal, as well as the metal adjacent to the seam, is exposed to the atmosphere unless it is protected with paint. You'll no doubt often see these miters welded, but it is not recommended as the best method.

Braze the corners of the door in the same manner you used on the miter jambs. File or sand off the excess bead, and fit the door in the jamb. The door should be slightly loose (have clearance all around). Insert thin strips of metal on all four sides of the door between the door and the jamb. This is done to insure that the door has equal clearance and to keep it from binding after the hinges are located and secured to the locker and door. Secure these hardware fittings on the locker with either rivets or machine screws. Your locker is ready for installation. You can hang it from hangers, or set it on a shelf bracket.

Unfortunately, all of the lockers that you may be called upon to construct will not be as simple as the one illustrated in figure 330. For example, lockers on submarines must fit the various curvatures of the hull, and consideration must be given to the manner in which you are going to get the locker down the hatch and into the sub. You'll need all the ingenuity at your command to master some of these problems. Think about and plan your job. Consider the problems from every angle before you break out your layout tools and start your layout. It's a bit embarrassing to build something and then find that it doesn't fit.

QUIZ

Select the one best answer to each of the following statements.

1. The weight of a piece of steel plate 3/16-inch x 12 inches x 24 inches is approximately—

    (*a*) 2½ pounds.
    (*b*) 5 pounds.
    (*c*) 7½ pounds.
    (*d*) 15 pounds.

2. The weight, in pounds per square foot, of a piece of 24 gage galvanized iron is—
   (*a*) 0.0239.
   (*b*) 1.156.
   (*c*) 6.5.
   (*d*) 10.0.

3. Inside circles in sheet metal should be cut with a—
   (*a*) Combination shear.
   (*b*) Squaring shear.
   (*c*) Hawksbill.
   (*d*) Bench shear.

4. The capacity for cutting alloy steel on a mild steel squaring shear will be—
   (*a*) 50% of the maximum capacity.
   (*b*) The same as for mild steel.
   (*c*) The maximum capacity minus 25%.
   (*d*) The alloy steel thickness minus $\frac{1}{16}$-inch.

5. Devices for clamping sheet metal in place on a squaring shear are known as—
   (*a*) Clamps
   (*b*) Hold-downs.
   (*c*) Guides.
   (*d*) Squares.

6. The power squaring shear is designed to cut—
   (*a*) Square stock.
   (*b*) Round stock.
   (*c*) Bar stock.
   (*d*) Sheet stock.

7. A power-driven hand tool used for curves, notches and straight line cuts on light sheet metal is the—
   (*a*) Unishear.
   (*b*) Power squaring shear.
   (*c*) Bench shear.
   (*d*) Throatless shear.

8. If a ring and circle machine is not available, an inside circle in heavy gage sheet metal may be made with a—
   (*a*) Grinder and buffer.
   (*b*) Combination snips.
   (*c*) Drill and file.
   (*d*) Manually operated squaring shear.

9. Hand bends are accomplished with a—
   (*a*) Pan brake
   (*b*) Cornice.
   (*c*) Mallet.
   (*d*) Dolly.

10. A machine which is used to make uniform bends in sheet metal is called a—
   (*a*) Cornice brake.
   (*b*) Stake.
   (*c*) Jig.
   (*d*) Bender.

11. A machine bend with a slight radius is obtained by—
   (*a*) Inserting a bending radius.
   (*b*) A partial machine bend and finished by hand.
   (*c*) Reversing the upper machine blade.
   (*d*) Setting for heavy gage and bending a lighter gage.

12. The allowance for a sharp machine bend is equal to the—
   (*a*) Metal thickness plus springback allowance.
   (*b*) Exact thickness of the metal.
   (*c*) Metal thickness plus or minus 1/64-inch.
   (*d*) Metal thickness plus outside radius elongation.

13. Spring-back allowance for machine bending hard and springy metal is compensated for by—
   (*a*) Raising lower bending leaf a few degrees more than for softmetal.
   (*b*) Adding the difference between the inside and outside bend radii to metal thickness.
   (*c*) Annealing the metal before bending.
   (*d*) Increasing machine pressure

14. The operation of making duplicate machine bends may be facilitated by using a—
   (*a*) Stake.
   (*b*) Dolly.
   (*c*) "Finger".
   (*d*) Stop gage.

15. An advantage of the Pittsburgh lock seam is that after forming in the shop, it may be assembled anywhere with a—
   (*a*) Hand brake.
   (*b*) Mallet.
   (*c*) Dolly.
   (*d*) Miter box.

16. A machine in which parts of the upper leaf may be removed for forming boxes is called a—

(a) Cornice brake.
(b) Mold
(c) "Finger" brake.
(d) Blowhorn stake.

17. In forming a cylinder on a slip-roll forming machine the desired radius is obtained by adjusting the—

(a) Top front roll.
(b) Lower front roll.
(c) Three rolls.
(d) Rear roll.

18. Conical shapes can be formed on a slip-roll machine by angular setting of the—

(a) Rear roll.
(b) Top front and rear roll.
(c) Twc front rolls.
(d) Base.

19. To complete a grooved seam on a cylinder, one would use a—

(a) Beakhorn stake.
(b) Block of wood.
(c) Hand groover.
(d) "Finger" brake.

20. When selecting a stake, the radius of the stake in relation to the object being formed should be—

(a) Slightly larger.
(b) Slightly smaller.
(c) The same size.
(d) One-half as large.

21. The preferred tool to form a bail would be a—

(a) Pair of pliers.
(b) Needle case stake.
(c) Vise.
(d) Creasing stake.

22. The metal forming process used in making a copper ball or float is known as—

(a) Mushrooming.
(b) Braking.
(c) Bumping.
(d) Drawing.

23. When cutting metal with a chisel, keep your eye on the—

(a) Chisel's cutting edge.
(b) Chisel head.
(c) Line of cut just ahead of the chisel.
(d) Hammer head.

24. The size designation of a tinner's rivet is based on the—

(a) Number per pound.
(b) Rivet's diameter.
(c) Weight per thousand.
(d) Length and diameter of the rivet.

25. When two pieces of metal are set-up close together with a rivet set, the term used is—

(a) Bucking.
(b) Drawing.
(c) Heading.
(d) Upsetting.

26. The process in which a machine turns an edge at right angles to form narrow flanges for seams or hems is called—

(a) Burring.
(b) Beading.
(c) Crimping.
(d) Turning.

27. The process where rounded flanges (edges having radii) are formed is called—

(a) Burring.
(b) Beading.
(c) Turning.
(d) Wiring.

28. The elbow-edging rolls produce a—

(a) V-groove.
(b) Bead.
(c) Half crimp.
(d) Flange.

29. The mashing down of a single seam to make it tight and smooth is called—

(a) Drawing.
(b) Crimping.
(c) Setting-down.
(d) Upsetting.

30. The process of shrinking the end of a metal cylinder so that it can be fitted into another cylinder of the same diameter is called—

(*a*) Drawing.
(*b*) Crimping.
(*c*) Setting-down.
(*d*) Grooving.

31. When using any edging machine with rolls, the seam—

(*a*) May go through the rolls with reduced pressure.
(*b*) Should not be formed until after edging.
(*c*) May go through rolls with negligible damage.
(*d*) Should not go through the rolls.

32. The clearance necessary in making a plain double seam should be equal to—

(*a*) One times the metal thickness, plus or minus 1/64-inch.
(*b*) Slightly more than the metal thickness.
(*c*) Two times the metal thickness.
(*d*) Slightly greater than seam thickness.

CHAPTER 13

BLACKSMITH WORK AND FORGING

YOU'RE ALSO A BLACKSMITH

It's a long way from the village smithy to the blacksmith shop in the hold of a modern warship, but the forging procedures in both shops remain about the same. Your job as Metalsmith requires on occasion that you know simple forging procedures. One of the best ways to learn is by helping an experienced workman. Observe how he handles the forging fire, heats the metal, hammers it into shape, and heat-treats it.

Forging is the name usually applied to a method of working and shaping metals while they are hot enough to be plastic. Another name for forging is hot-working. The forging process, when properly carried out, does not damage the metal; in fact, it actually improves its properties. The grain structure of steel is refined by forging—the large grains of the metal are broken up to form a strong, fine-grain structure.

While many different metals may be successfully shaped by forging, most of your work will be with FERROUS metals—

wrought iron; low-, medium-, and high-carbon steels; and special tool and alloy steels.

Wrought iron is forged into chain links, hooks, and other small fittings. It is readily forged and has good properties of shock and corrosion-resistance. Wrought iron is seldom cold-worked. It cannot be hardened by heat-treatment. Due to the development of alloy steels and gas and arc welding, wrought iron is not used as much by the Navy as formerly. That's one reason the old Navy rating of Blacksmith has been abolished.

STEEL FORGINGS are used extensively in the manufacture of ship fittings, machinery, and other shipboard gear. Most of YOUR forging will be the making of small parts and fittings and shop tools, jigs, and gages. For such work you'll use low-carbon steel—steel containing about 0.25 per cent of carbon. Ordinarily you won't have the heavy, expensive, and elaborate equipment necessary for forging large pieces. The first step in successful forging is the selection of proper material of correct dimensions.

SELECTING STOCK

To select stock of the correct dimensions, you must first decide how the part is to be forged. One method is to select stock a little larger than the largest dimensions of the part to be forged and obtain the smaller size by working it down on the anvil. The opposite method is to choose stock about the size of the smaller dimension. You can then increase its cross-sectional diameter to the required size by using the hammer and anvil. These processes, known as drawing and upsetting, are forging procedures discussed later in this chapter.

In either case, it is good practice to estimate the cubic content of the finished product. Choose stock sufficiently large to give the cubic content, allowing ample for squaring up the end and for scaling. The loss due to scaling will vary with the number of reheatings and with the atmosphere and temperature of heating.

Steel is forged at temperatures that are well above the critical range but also well below the melting point. You may not have temperature-measuring equipment, so learn to judge temperatures by the colors of the hot iron or steel. Use figure 44 as a guide.

For good forging, the metal must be heated uniformly. All parts should be the same temperature all the way through. Too rapid heating will cause uneven expansion of the metal, thus starting cracks. This is especially dangerous in high-carbon and high-alloy steels. Forging temperatures too high for the amount of work to be done will cause large grains in the finished forging. If the forging is heated excessively (that is, to the melting range) there will be voids (holes) and oxide

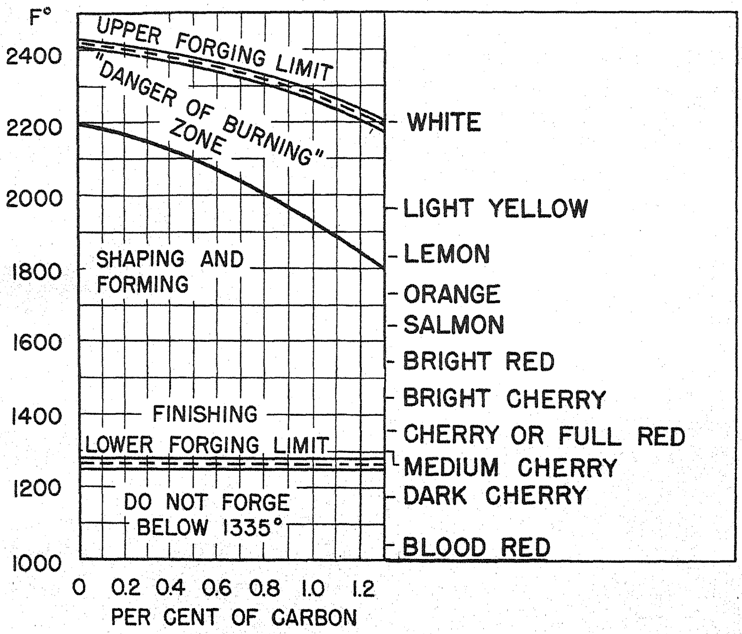


Figure 331.—Forging temperatures for steel.

(scale) inclusions in the final product. This is commonly called burning. Oxide forms as a crust on metal which is heated excessively and may be overlapped by the metal, forming a weak spot. Continuing the forging at temperatures too low will leave the steel in a highly stressed state. This should be avoided as it will result in a short life for the finished product. But if it does happen, you should apply some form of heat-treatment.

Now take a look at figure 331. Notice that when your heated steel reached a lemon color at about 1800° F. it can be forged. For pieces requiring more forging, heat to higher temperatures. You can continue forging until the color changes to a cherry or full red at somewhere between 1300° F. and 1400° F. The final forging blows are struck at this point and are continued until the full red color begins to change to a dark cherry red at about 1350° F. If the forging is not continued to the lower temperature, the structure of the steel will be weakened and the grains will "grow" to larger size because of the heat retained in the stock.

Wrought iron may be forged at the temperatures indicated for steel which contains less than 0.1 per cent carbon.

HEATING METHODS

If you do much forging, you will use an OIL-BURNING FORGE. One of these, of the type used on some cruisers, is shown in figure 332.

The AIR and OIL supplies of this forge are controlled with hand valves. To light off the forge, always open the air valve first to give the burner a little air. Then apply a light, preferably a piece of lighted waste. When you have the light in place, crack the oil valve and continue opening it until it catches and you have the flame burning.

After a few minutes, turn on more air. The flame will turn into a roaring blast of heat that is almost colorless. The best flame for an oil-burning forge is one that is CLEAR and SMOKELESS. A lot of black smoke means that you are using too much oil.

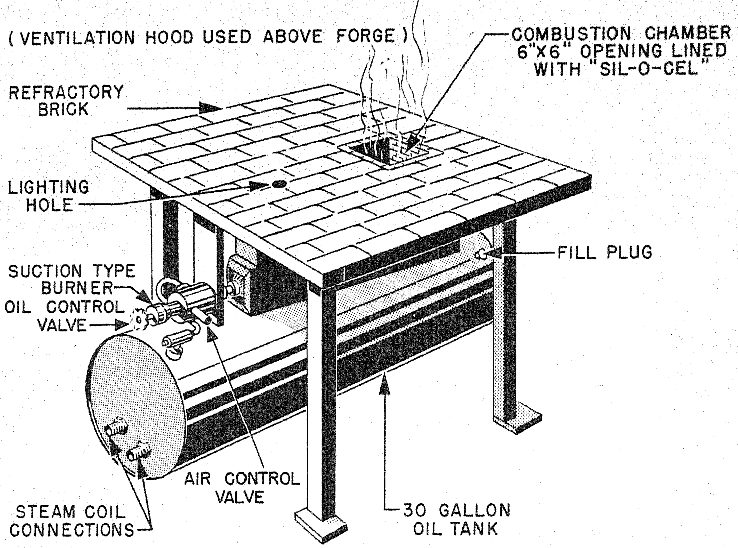


Figure 332. — Oil-burning forge.

When you secure the burner, always TURN OFF THE OIL FIRST. Then turn off the air.

Heat-treating furnaces are sometimes used to heat metal for forging (see figure 54). These furnaces are somewhat slower than the oil-burning forge. Also, ALL of the piece to be forged must be heated, which may be a disadvantage. When using a forge, you heat only the area which is to be forged. You will not be apt to find these furnaces on small ships, but it is not uncommon to find one of the type pictured in figure 54 aboard repair ships or on shore stations where the type of work requires them.

On the smaller ships the methods for emergency forging jobs must be improvised. You can heat pieces of metal for forging with your oxyactylene welding torch by playing the flame over the metal that is to be forged until it is uniformly heated. A pair of gasoline torches may also be used for heating small jobs. Also, on some of the smaller ships you may find the small hand-operated forge similar to the one shown in

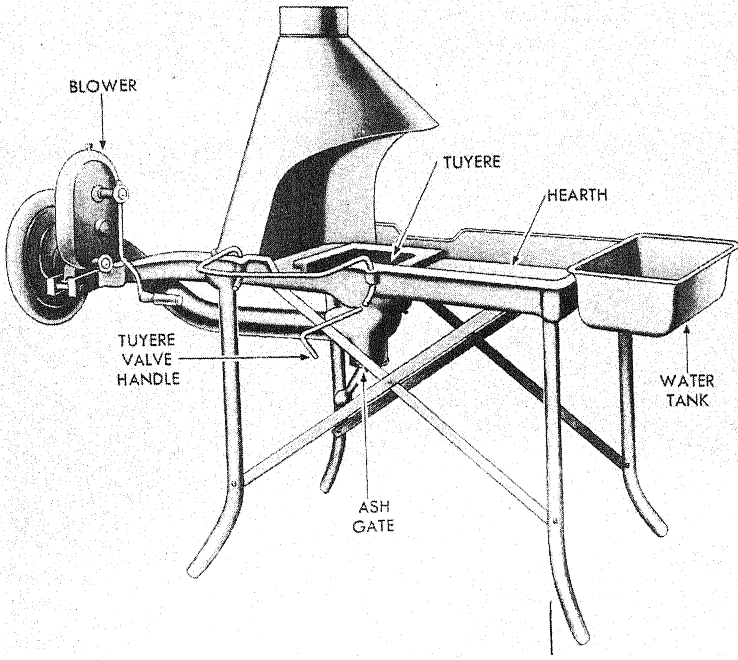


Figure 333.—Hand-operated portable forge.

figure 333. Just remember that regardless of the method of heating, the same rules apply concerning heat and working of the metal.

FORGING TOOLS

The tools used at the anvil with hand hammers or sledge hammers are swages, fullers, set hammers, flatters, punches, and chisels with tongs to hold the work.

The anvil is one of the most used of all the Metalsmith's tools. Its face is a smooth flat surface made of tough steel. The face must be treated with care to keep its surface smooth and free of dents and scratches. This provides a working surface that will support the metal while it is being pounded into shape. The smoother the face the better job you will get. The

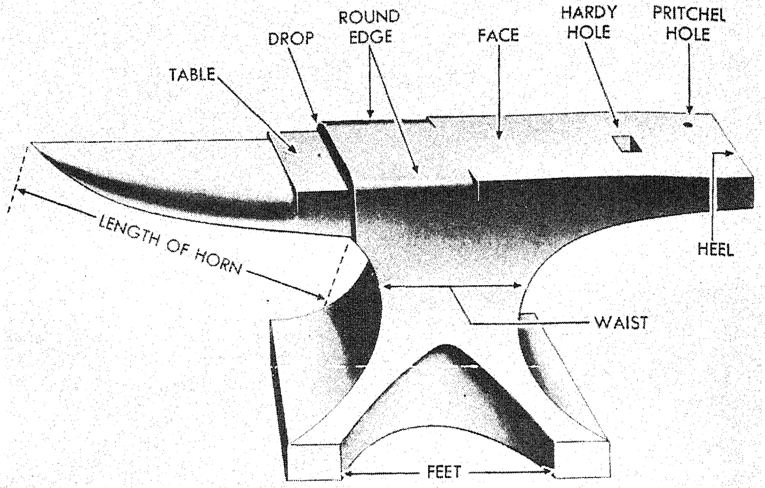


Figure 334.—Blacksmith's anvil.

cone-shaped end of the anvil, called the horn, is used for shaping and forming curved bars or rods. The square hole in the face of the anvil is used for holding the hardy tools.

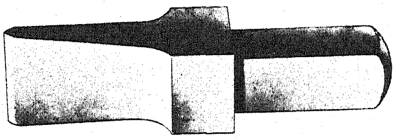


Figure 335.—Hardy cutter.

The hardy cutter is a hot and cold chisel made to fit into the hardy hole of the anvil. It is mainly used as a bottom-cutting tool. Metal is cut by placing it on the hardy cutter and striking it with a hand hammer. It is used for cutting metal bars and rods, and it may be used on steels (both hot and cold).

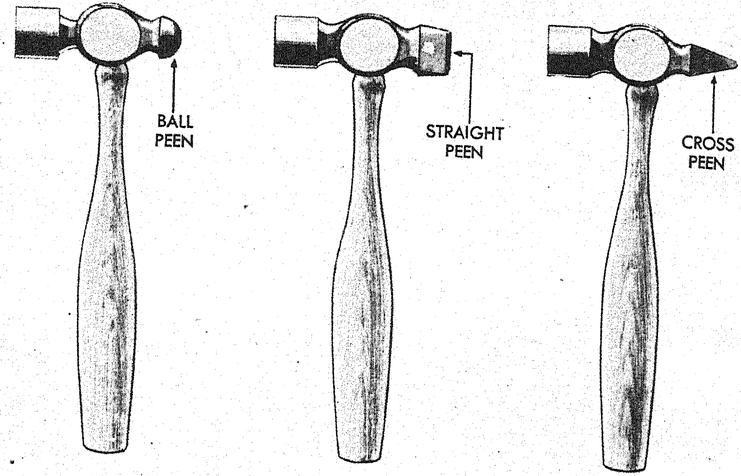


Figure 336.—Blacksmith's hammers.

Three types of hammers (see figure 336) are used in forging operations. These are the ball-peen, straight-peen, and cross-peen. Of these, the ball-peen hammer is the one most generally used as it is most suitable for ordinary light work. The straight-peen hammer is used mainly for drawing out stock at right angles

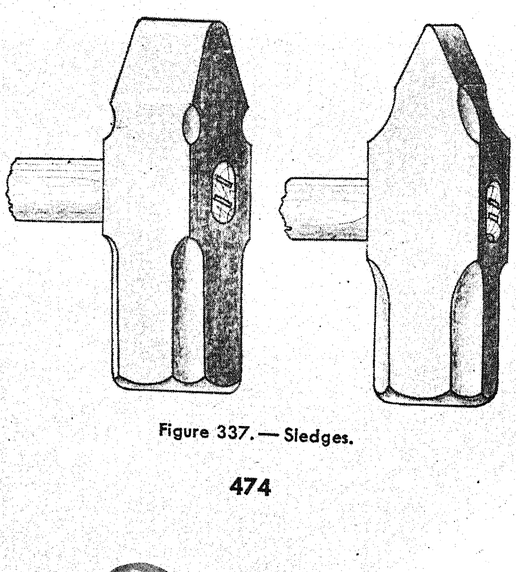


Figure 337.—Sledges.

to the hammer. The cross-peen hammer is used to draw out metal in line with the hammer handle.

A sledge is a hammer weighing from five to twenty pounds and having a handle 30 to 36 inches long. It is usually of a straight-peen or cross-peen type, as shown in figure 337. Sledges are used for heavy forging. Ordinarily they are used by the Metalsmith's helper to strike heavy blows, either directly on the work or on some other tool, such as a swage, fuller, or flatter.

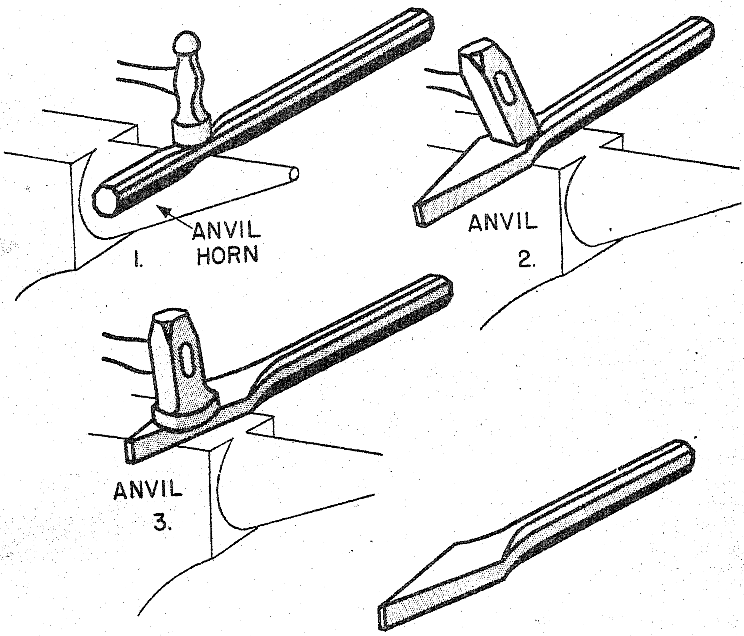


Figure 338.—Using hammers to forge a cape chisel.

Now take a look at figure 338. The use of three different types of blacksmith's hammers is illustrated. In the first step the ball-peen hammer is used over the horn of the anvil to make the indentation in the stock. With a ball-peen hammer the force may be applied to a small area. In the second step the sledge is used on the face of the anvil for the actual working of the cape chisel. The weight of the sledge and the working

of the stock on the face of the anvil shape the chisel. In the third step the flatter is used for finishing the chisel. The use of the flatter will give a smooth surface and eliminates hammer marks and inclusions.

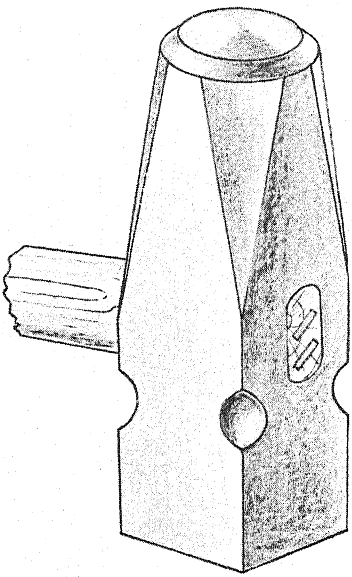


Figure 339. — Set hammer.

The set hammer (figure 339) is used for working in small spaces, or producing small inside corners. It is usually made with sharp edges, although some set hammers have round edges and are called round-edge set hammers. The set hammer is one of the most useful tools for forge work. However, its use requires a helper.

The Flatter (see figure 340) is like the set hammer except that the face is larger than the body. It is used in much the same way for smoothing work and for producing a finished appearance by taking out the uneven surface left on stock by the hammer or other tools. Its use also requires a helper.

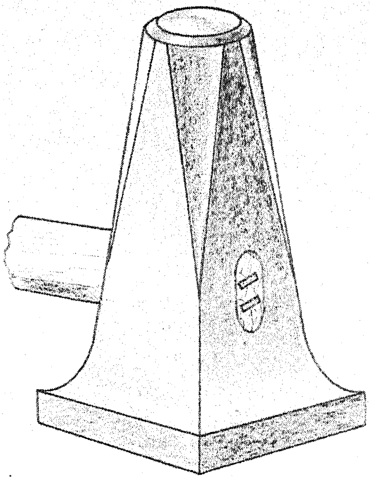


Figure 340.—Flatter.

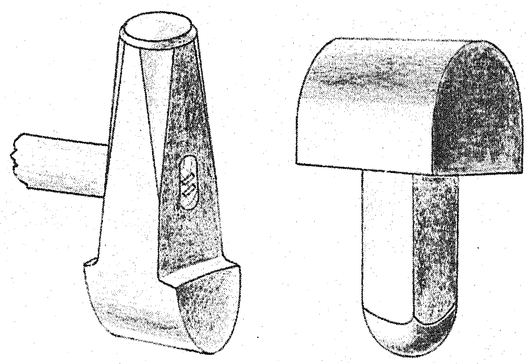


Figure 341.—Fullers.

Fullers are used to shape round inside corners and angles. When the forging is worked between the top and bottom fullers, the top fuller is struck with a sledge. The top fuller is often used alone to make depressions on the upper side of the forging as it lies flat on the anvil. It has a handle like a hammer and is held on the work by a Metalsmith while his helper strikes it

with a sledge. The bottom fuller (figure 341) fits into the hardy hole of the anvil. It serves the same purpose as the top fuller. To use the bottom fuller for making depressions in stock, insert it in the hardy hole and place the stock on top of it. The stock is then struck directly with a sledge until the required size, shape, or depression is made. Fullers are ordinarily made with radii of ½ to 1½ inches.

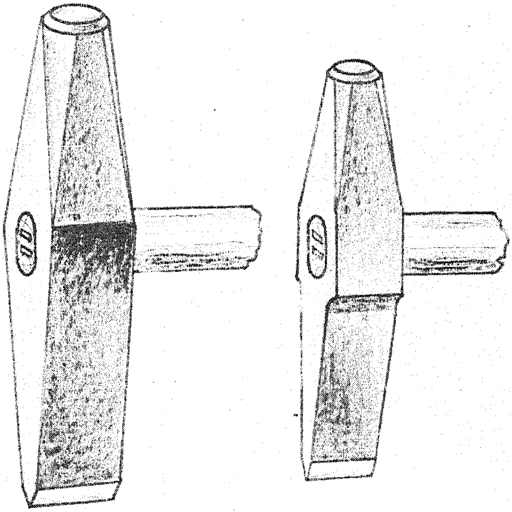


Figure 342.— Chisels.

Chisels are special tools used for cutting or splitting hot [illegible] cold stock. The hot chisel is used for cutting hot metal. The cold chisel is used for cutting cold metal. The hot chisel is thinner than the cold chisel. Its edge is made thin so that it will penetrate heated metal quickly. The edge can be made thin because great strength is not required of a tool for cutting hot metal. The cutting edge of the hot chisel is ground to an included angle of about 30 degrees. The cold chisel is [illegible] stubby and blunt to give it greater strength. The cutting edge is ground to an included angle of about 60 degrees. Blacksmith's chisels are usually fitted with a handle. They are held

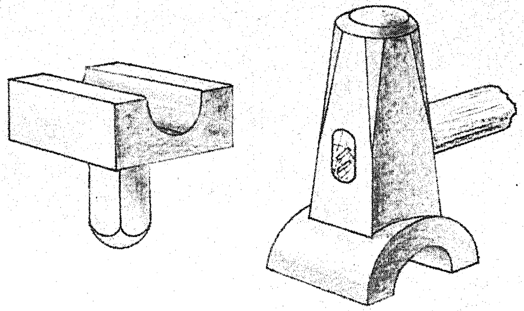


Figure 343.— Swages.

in place by the blacksmith and struck with a sledge by his helper.

Swages (see figure 343) are used for smoothing and finishing. They are made up in all sizes, depending upon the work for which they are intended. They are used in pairs, each consisting of a bottom and a top swage. The bottom swage is inserted in the hardy hole of the anvil. The groove in the top swage is the same size and shape as that in the bottom swage. Grooves are usually made half-round, octagonal, or square, although they may be made in any other shape. A hot forging is placed in the groove of the bottom swage, and the top swage is held on top of the work by the Metalsmith while his helper strikes it with a hammer.

You may also have a swage block like the one in figure 344. Made of cast iron or steel, the block weighs about 150 pounds and is commonly mounted on a stand. It is cast with a number of round, square, and rectangular holes, and provided with grooves of various shapes and sizes around the edge. This block is useful in the forming of all kinds of shapes. The holes are mostly used for the insertion of work that is being headed, such as bolts. The grooves are used principally as [illegible] swages.

Punches are used for making round, square, or odd-shaped holes in hot metal. Like most of the other forging tools described, they are provided with handles and are held on the

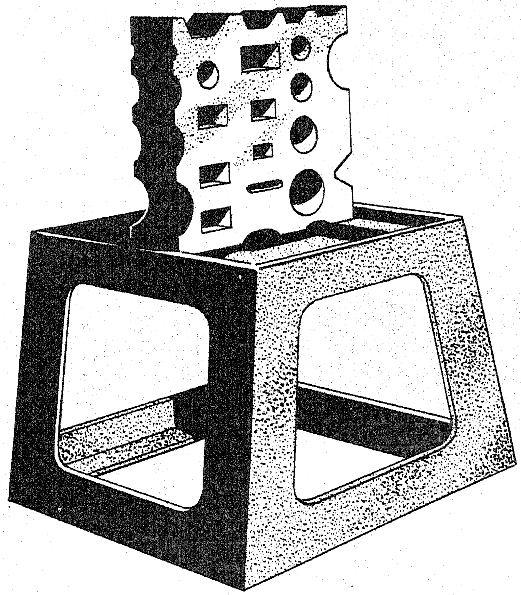


Figure 344. — Swage block.

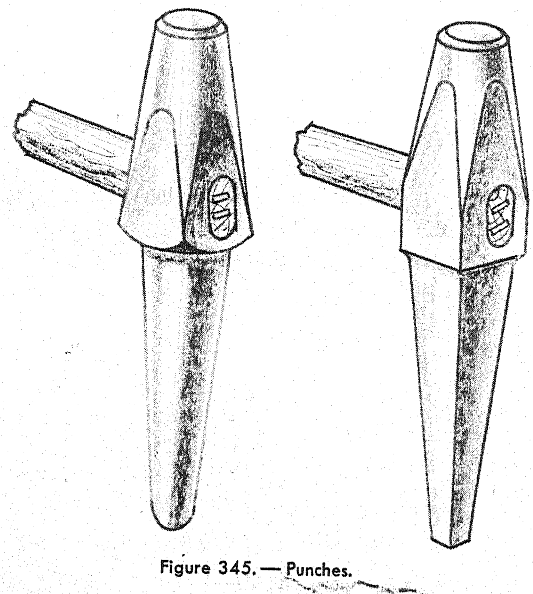


Figure 345. — Punches.

work by the Metalsmith while being struck with a sledge by his helper. When finishing a hole the punch is held on the work over the pritchel hole of the anvil, which permits the slug of the stock to drop through.

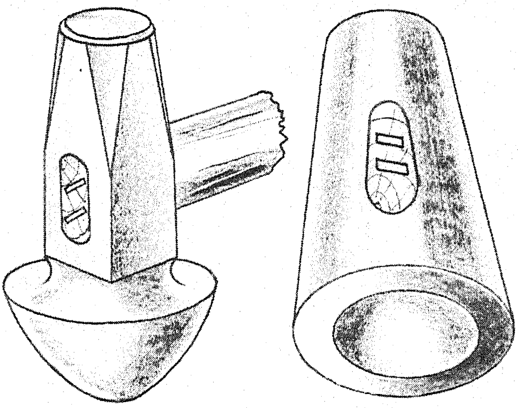


Figure 346.—Bob and cupping tool.

Two other handy tools are the bob or counterpunch and the cupping tool (see figure 346). The counterpunch is used for countersinking holes and making depressions for jump welds

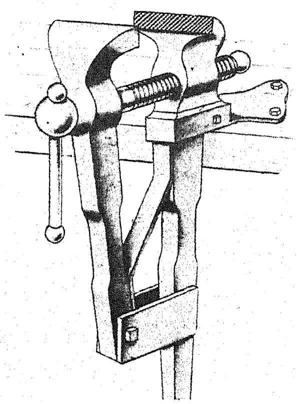


Figure 347.—Blacksmith's vise.

(see figure 358). The cupping tool is used for rounding off or finishing the heads of rivets.

A vise has many uses in the blacksmith shop. It is used for holding work while it is being laid out, bent, twisted, or filed. A good type of vise is shown in figure 347.

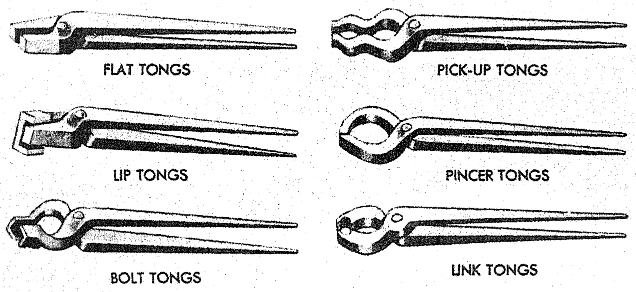


Figure 348.—Common tongs.

Tongs are used to hold hot work during forging on the anvil They should be well constructed and fitted to the work they are made to hold. They are usually made by the Metalsmith either for general use or for a special purpose. Both sides of most pairs of tongs are alike. All of their dimensions, offsets, projections, and curves are in the same direction. To assemble, one side is turned over and they are riveted together. There are six types of tongs in common use in the blacksmith shop. These six definite forms are shown in figure 348.

Special tongs are those made for a special purpose. As a Metalsmith you will find that frequently you will have no tool with which to do a particular job. It is at this point that you begin to invent. Figure 349 shows a few of the special-purpose tongs that may be made to do a particular job.

A special blacksmith's surface plate which has a smooth flat face is a standard piece of equipment in the larger shops. It is used to test the surfaces and shapes of forged pieces.

Many tools have been designed for use in the blacksmith shop, but you will find that in many cases your jobs will call for tools that are not available. Here is where the job begins.

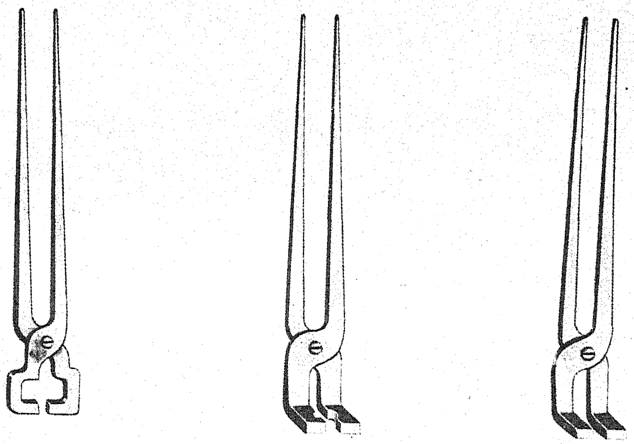


Figure 349.— Special tongs.

Get the right tools for the job—make them if you have to, and use the tool for the job for which it is intended.

FORGING PRACTICE

Here are some important items for you to consider and remember when you are doing forge work—

1. CONTROL THE HEATING so that it is uniform over the entire area to be forged.
2. AVOID OVERHEATING the metal—watch those heat colors.
3. PLAN YOUR WORK so that the finishing blows are applied as the steel begins to lose full color.
4. AVOID REPEATED REHEATING of the metal. Try to do all the forging with one heat. Repeated reheating will enlarge the grain and weaken the structure.
5. KEEP HAMMER HANDLES TIGHTLY WEDGED so the heads won't fly off. The handles loosen because the heat shrinks the wood.
6. MAKE SURE THE FORGE FIRE IS OUT before you knock off work.

7. HAVE PLENTY OF RESPECT FOR HOT METAL. Wear special leather clothing when you do forging.

FORGING OPERATIONS

When heated to the proper forging temperature, steel and soft iron can be hammered into almost any desired shape. The various hammering operations are known as DRAWING, UPSETTING, BENDING, and WELDING.

DRAWING is a method of working a piece of metal so as to increase its length or width, or both, and to reduce its cross section. When both length and width are to be increased, the metal is hammered over the flat face of the anvil. Length only is increased by hammering the metal over the anvil horn, as shown in figure 350. The horn acts as a blunt wedge to spread the metal and force it lengthwise.

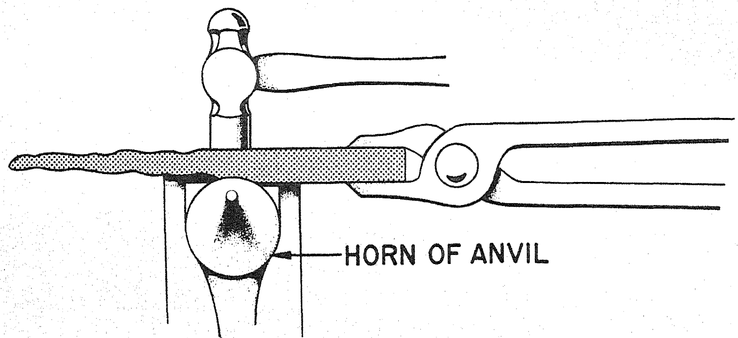


Figure 350.— Drawing operation on flat stock.

Round stock may be drawn out or pointed by the method shown in figure 351. Forge it square first, then octagonal, and then round again. Remember to forge it with as few blows as possible. Try to do all the forging without reheating.

UPSETTING is the reverse of drawing—that is, the length is decreased and the cross section is increased. A somewhat higher temperature is required for upsetting than for drawing. The temperature must be near the upper forging limit.

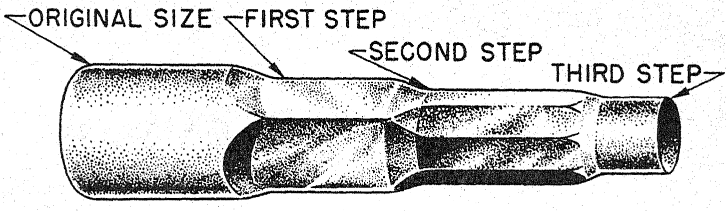


Figure 351.—Drawing round stock.

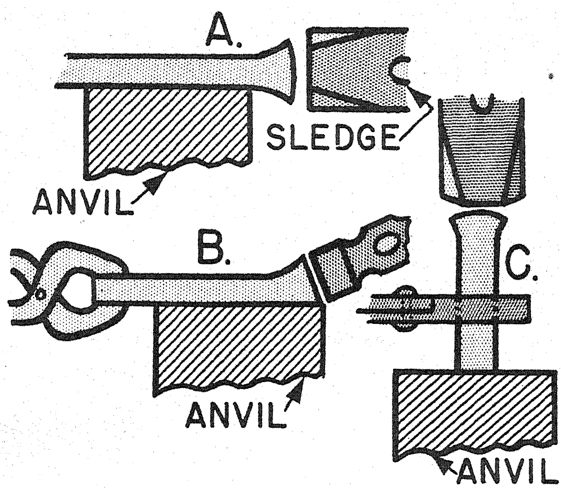


Figure 352.—Upsetting.

A SHORT piece of steel is upset easily by placing it on the anvil and striking it with a hammer or sledge. Longer pieces must be held with tongs. When a long piece bends while it is being upset, it should be straightened immediately. Only the portion of the metal to be upset is heated. The upsetting may be done by the method shown in figure 352.

Shouldering is usually accomplished by upsetting and drawing. In forming a rivet, for example, use your fullers to make a depression just below where the head is to be. Start drawing out from the small end and work up to the depression. When

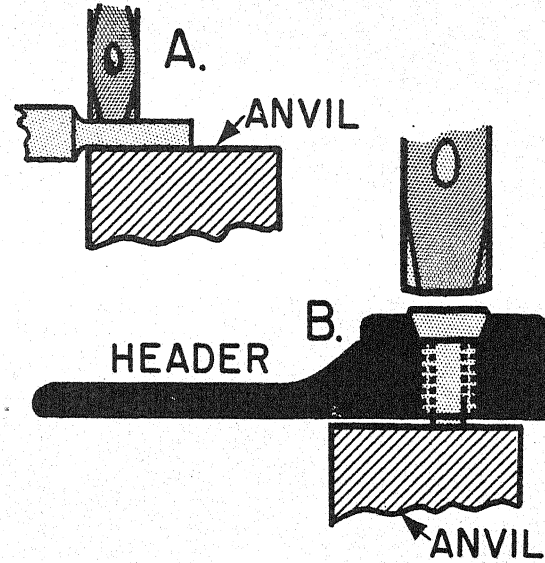


Figure 353. — Shouldering.

the proper size and shape has been formed, quench the body of the rivet, using a header like the one shown in figure 353, and upset the head.

HOT BENDING

SQUARE and ANGLE bends may be formed over an edge of the anvil face as shown in figure 354. The metal is held down by a helper with a heavy sledge. Notice that the bend is started at the end of the piece and not at the point of bend. The bend may be finished square inside and out, or rounded. If an inside radius is desired, the metal is bent over a rounded corner of the anvil.

An angle bend will be stronger if the area of the portion to be bent is enlarged by upsetting. To upset the rod or bar, just heat it at the point of bend and—holding it vertically by one end—strike the other end against the deck. Then bend the

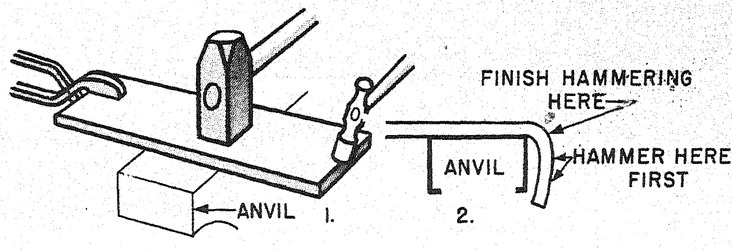


Figure 354.—Square and angle bends.

rod or bar in a vise or over an anvil to the desired angle, using the extra metal to reinforce the bend.

Curved bends are started over the rounded anvil horn (figure 355). Notice that the curve is started at the end of the piece (figure 356). Rings are also forged in this manner.

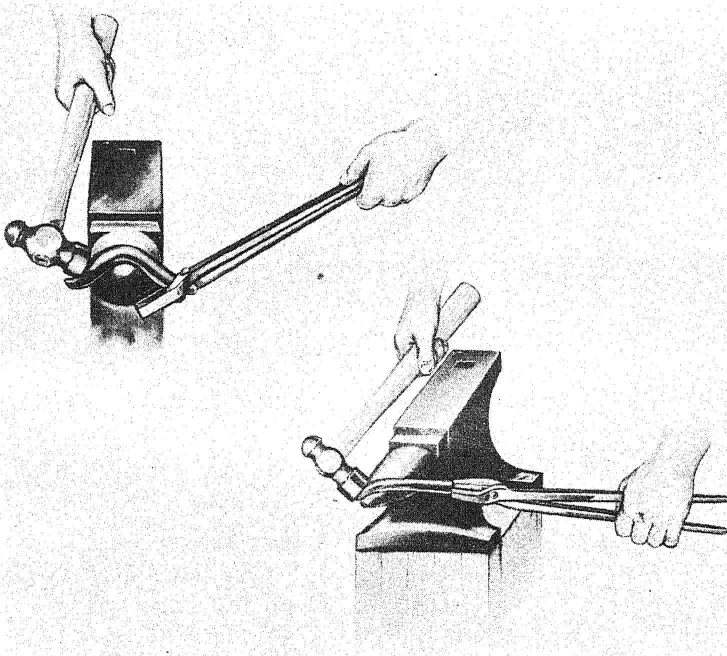


Figure 355.—Bending.

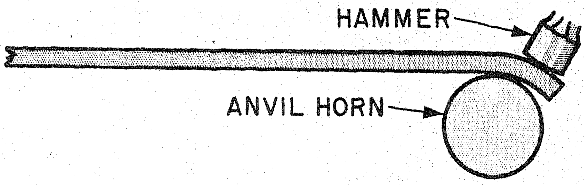


Figure 356.—Starting a curved bend.

One method of bending an eye is illustrated step by step in figure 357. The bend is started over the edge of the anvil in step 1, and completed around the horn to desired size in steps 2, 3, and 4. It looks easy, but you'll have some trouble keeping the curve straight at first.

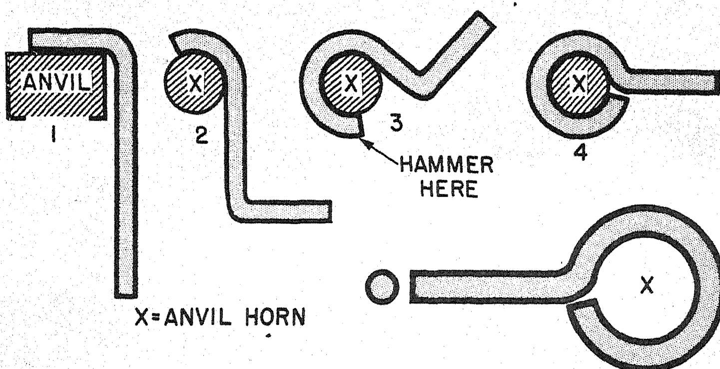


Figure 357.—Bending an eye around an anvil horn.

FORGE WELDING

Forge welding of steel or iron requires that the parts be heated to a temperature of 2500° F. or more, and then hammered together. To avoid burning, the metal should be welded as soon as it reaches the proper temperature. It won't weld when it cools, so make every blow count.

The ends to be joined should be preshaped by forging or cutting to one of the shapes illustrated in figure 358. The

operation of preparing the pieces for welding is known as scarfing. The beveled end is known as the scarf. Notice the extra metal provided at the joints. If the extra metal is not provided the welded area will be thinner and weaker than the rest of the piece. When finished, the weld is worked down to size, either with hammer and anvil or with swages.

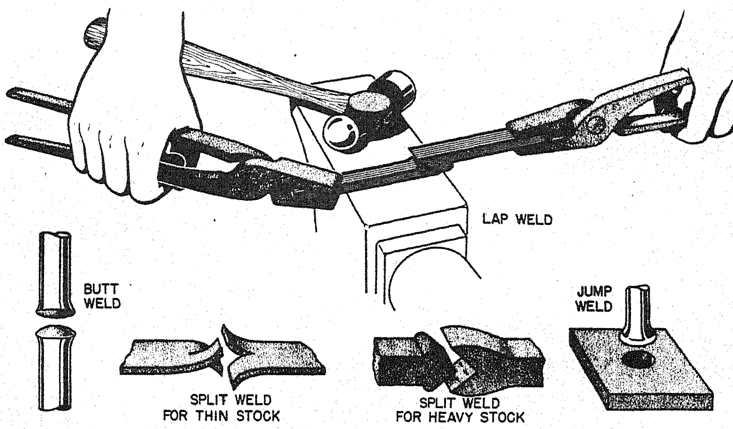


Figure 358.— Joints for forge welding.

When wrought iron or steel is heated to high temperatures, such as used in welding, and are exposed to air, they oxidize rapidly. To secure a bond between two pieces, this oxide must be so fluid that it can be squeezed out from between the surfaces. The fusion point of the oxide is lowered by the use of fluxes.

Clean silica sand and borax are the two common fluxes used at the forge. Borax has a low fusion point. Because of this it is used on high-carbon steel. It can be placed on the steel at low temperatures after scarfing or it can be sprinkled on the steel while the steel is heating. Borax lowers the fusion point of the oxide and prevents further oxidation. Sand has a high fusion temperature, but when it is combined with iron oxide it becomes fusible at lower temperatures. It is generally sprinkled on the metal just before it reaches the welding temperature.

Because of the development of gas-and arc-welding equipment and the availability of this equipment on ships and stations, you'll not do much forge welding, but in case you do, it is a good idea to have the information at hand.

DO THE JOB

Now you have the fundamentals for doing blacksmith work and forging, but you will find that there is nothing that will substitute for practice. Study the color chart until you know by looking just how hot a piece of metal really is. Get acquainted with the tools that are available, but remember that sometimes there will be no tool for doing the job that will come up. That will call for initiative. There is always a way if you just use common sense and apply it to the material at hand.

QUIZ

Select the one best answer to each of the following statements.

1. Another name sometimes used for forging is—
   (*a*) Cold-working.
   (*b*) Welding.
   (*c*) Scarfing.
   (*d*) Hot-working.

2. Forging is the name applied to a method of working metals while they are hot enough to be—
   (*a*) Molten.
   (*b*) Malleable.
   (*c*) Puddled.
   (*d*) Vaporized.

3. The first step in successful forging is to—
   (*a*) Measure the critical range.
   (*b*) Remove scales caused by preheating.
   (*c*) Estimate cubic content of finished product.
   (*d*) Add 25% to selected stock for loss due to scaling.

4. The most practical way to judge temperature is to—
   (*a*) Learn colors of hot iron and steel.
   (*b*) Watch the forge flame.
   (*c*) Keep a color chart in your pocket.
   (*d*) Memorize the melting points of metal.

5. In the process of forging metal, the grain structure is—
   (*a*) Enlarged.
   (*b*) Refined.
   (*c*) Made brittle.
   (*d*) Made coarse.

6. The result in the finished forging where temperatures are too high for the amount of work to be done will be—
   (*a*) Small structural grains.
   (*b*) Internal air pockets.
   (*c*) High stresses.
   (*d*) Large structural grains.

7. If a piece of steel containing 0.2 percent carbon is heated to 1550°F., its color will be—
   (*a*) White.
   (*b*) Lemon.
   (*c*) Bright red.
   (*d*) Blood red.

8. It is preferrable to light an oil-burning forge with—
   (*a*) Lighted waste.
   (*b*) A match.
   (*c*) An electric spark.
   (*d*) A friction sparklighter.

9. Black smoke in the heating chamber of an oil-burning forge is an indication—
   (*a*) Of impurities in the fuel supply.
   (*b*) That the correct proportion of oil to air has been reached.
   (*c*) That too much oil is being used.
   (*d*) That too much air is being used.

10. One of the most used of all blacksmith's tools is the—
    (*a*) Hacksaw.
    (*b*) Anvil.
    (*c*) Punch.
    (*d*) Chisel.

11. The cone-shaped end of an anvil is known as the—
    (*a*) Waist.
    (*b*) Harlie.
    (c) Shank.
    (*d*) Horn.

12. The hardie is used mainly as a—
    (*a*) Cape chisel.
    (*b*) Flatter.
    (*c*) Bottom cutting tool.
    (*d*) Fuller.

13. In setting down work, working in small spaces, or producing small inside corners, it is advantageous to use a —
   (*a*) Straight-peen hammer.
   (*b*) Cross-peen hammer.
   (*c*) Ball-peen hammer.
   (*d*) Set hammer.

14. The cutting edge of a cold chisel is ground to an included angle of about—
   (*a*) 30°.
   (*b*) 60°.
   (*c*) 90°.
   (*d*) 120°.

15. Blacksmith's chisels are usually—
   (*a*) Held with tongs.
   (*b*) Held by grasping the shank.
   (*c*) Placed in the anvil hardie hole.
   (*d*) Fitted with a handle.

16. Swages are used for—
   (*a*) Cutting and splitting.
   (*b*) Smoothing and finishing.
   (*c*) Shaping round corners.
   (*d*) Setting down work.

17. The tool used to make round, square or odd-shaped holes in hot metal is a—
   (*a*) Punch.
   (*b*) Swaging block.
   (*c*) Pritchel hole of an anvil.
   (*d*) Counterpunch.

18. The tool used to make a depression for a jump weld is a—
   (*a*) Cupping tool.
   (*b*) Odd-shaped punch.
   (*c*) Bob tool.
   (*d*) Swage.

19. Hot work is usually held in place, during forging on the anvil, with—
   (*a*) Tongs.
   (*b*) Pliers.
   (*c*) Tack welds.
   (*d*) A hardie hole

20. When a piece of metal is increased in length or width and the cross-sectional area reduced, the forging operation is known as—

(*a*) Upsetting.
(*b*) Scarfing.
(*c*) Drawing.
(*d*) Bending.

21. When the length of metal is decreased and its cross-sectional area increased, the forging operation is known as—

(*a*) Drawing.
(*b*) Bending.
(*c*) Scarfing.
(*d*) Upsetting.

22. An angle bend will be stronger if the area of the portion to be bent is—

(*a*) Drawn.
(*b*) Upset.
(*c*) Shouldered.
(*d*) Scarfed.

23. Forge welding requires parts to be heated to a temperature of—

(*a*) 1150°.
(*b*) 1400°.
(*c*) 1800°.
(*d*) 2500°.

24. The operation of preparing the pieces for forge welding is known as—

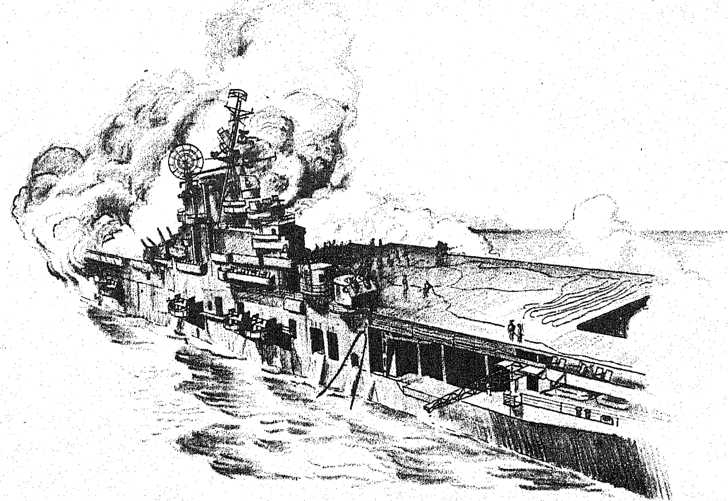
(*a*) Beveling.
(*b*) Preheating.
(*c*) Scarfing.
(*d*) Scaling.

25. When finished, a forge weld may be worked down to size with—

(*a*) Swages.
(*b*) A bob tool.
(*c*) Set hammer.
(*d*) Chisel.

26. Common fluxes used in forge welding are—

(*a*) Borax and sal-ammoniac.
(*b*) Tallow and rosin.
(*c*) Silica sand and borax.
(*d*) Stearine and stearic acid.



CHAPTER 14

EMERGENCY DUTIES

When your ship puts out to sea, she must be kept in a constant state of readiness. That is your job and the job of every officer and man aboard. All hands must turn to on a mission to—

1. KEEP THE SHIP AFLOAT.
2. KEEP THE SHIP UNDER WAY.
3. KEEP THE GUNS FIRING OR READY TO FIRE.
4. PROTECT THE LIVES OF THE CREW.

Your routine duties help to accomplish these purposes, but there will be frequent drills and instructions in the duties that you will be called upon to perform in case of an emergency. You will be assigned to a damage-control party and you will be trained to work when and where assigned at short notice.

Much of your knowledge and skills will be overlapping with that of the Damage Controlman who is responsible for the knowledge, theory, techniques, skills, and equipment of fire fighting, chemical warfare, carpentry, painting, and damage

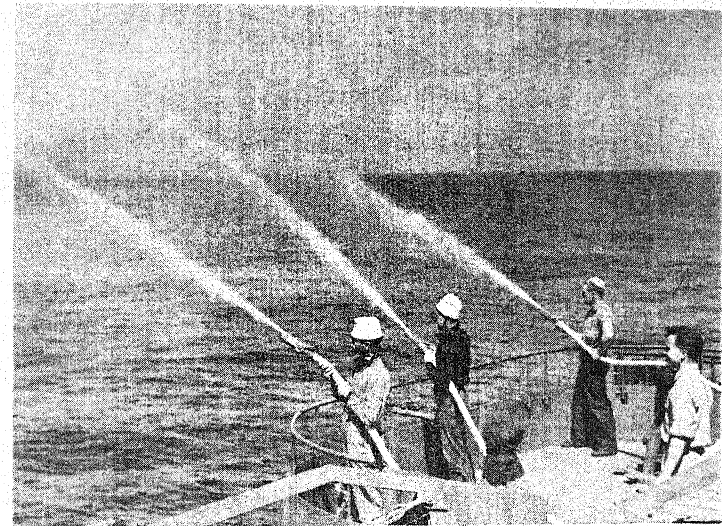


Figure 359. — Fire drill.

control. But there will also be much for you to learn concerning FIRE FIGHTING, WATERTIGHT INTEGRITY, AND DAMAGE CONTROL.

The causes of damage to a ship are FIRE, ENEMY ACTION, WEATHER, COLLISION OR OTHER ACCIDENT. You may encounter several kinds of trouble at the same time, so it is well to know how best to apply your tools and knowledge to maintain the safety, security, and effectiveness of your ship.

WATERTIGHT INTEGRITY

Watertight Integrity is built into the ship and, as a member of a damage-control party, one of your most important duties will be the checking and repairing of the ship's decks, bulkheads, and fittings to maintain that watertight integrity.

Such routine testing, checking, and repairing of watertight installations are apt to be somewhat monotonous, but they must never be taken lightly. Eternal vigilance is the price of your ship's safety. Just one fitting in bad shape may let in enough water to endanger your ship. That's why you have to

be sure that ALL the boundaries and fittings are in good condition all the time.

COMPARTMENTATION

Your ship is divided into compartments by BULKHEADS, which are vertical partitions, and by DECKS. Bulkheads running fore and aft are called longitudinal bulkheads and those running from port to starboard are called transverse bulkheads.

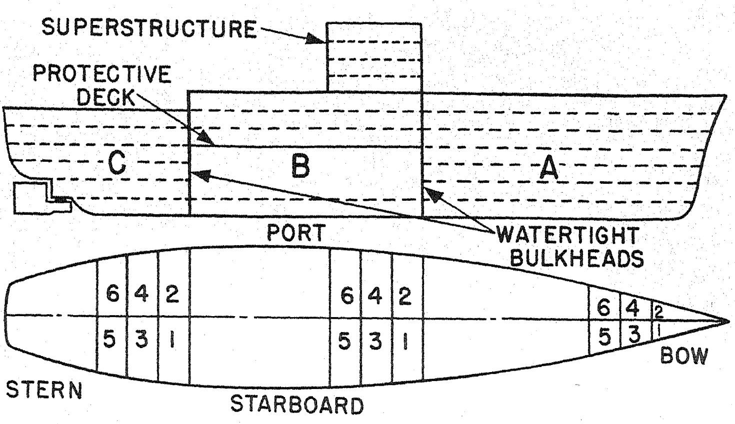


Figure 360. — Divisions of a ship.

The MAIN DECK is the highest deck extending completely from stem to stern and from port to starboard. The FORECASTLE DECK is a partial deck above the main deck forward. If such a deck extends well back into the waist of the ship it is known as the UPPER DECK. The POOP DECK is a partial deck at the stern. If it extends to the waist of the ship it is also called an upper deck. Likewise, a partial deck above the main deck amidships is an upper deck. SUPERSTRUCTURE DECKS are those above the forecastle, poop, and upper decks. On some ships, superstructure decks do not extend to the side of the ship.

Below the main deck the first complete deck is called the SECOND DECK. The next lower complete deck is called the THIRD DECK. In the case of large carriers there is a FOURTH DECK. A HALF DECK is a partial deck located between the main

deck and the lowest complete deck, and a partial deck located below the lowest complete deck is called a PLATFORM DECK. If your ship has more than one platform deck, they are designated FIRST PLATFORM, SECOND PLATFORM, from topside down.

Some of the decks and bulkheads are heavier-armored than others. The PROTECTIVE DECK is the heaviest-armored deck of the ship. A special steel armor plating is secured on top of the regular deck over certain vulnerable portions of the ship. This armor is usually on the second deck and covers such spaces as magazines and steering engine rooms. A SPLINTER DECK is an armored deck below the protective deck that has lighter armor than the protective deck.

COLLISION BULKHEADS are also made of heavier plate than ordinary watertight bulkheads. They are reinforced with stiffeners made of angles, bars, channels, and other structural shapes. These bulkheads are designed to prevent flooding of the rest of the ship in case the bow or stern is damaged by ramming or collision. The bow collision bulkhead is the first transverse bulkhead aft of the stem. The last transverse bulkhead aft is the collision bulkhead that protects the after part of the ship. SWASH BULKHEADS are partial bulkheads pierced by holes and installed in oilers and deep oil tanks in other vessels to prevent excessive movement of the liquid in the tank and thus reduce stresses in the ship's structure. WATERTIGHT BULKHEADS are usually made of heavier plate than ordinary bulkheads. In some ships these watertight bulkheads extend from the keel to the main deck without any access openings. Other ships have watertight doors in these bulkheads only on the second deck, with bulkheads below the second deck pierced only for essential services such as piping and wiring.

The effectiveness of damage control procedures is based on proper compartmentation of the ship. The ship is divided into compartments to—

1. Control flooding.
2. Restrict chemical agents and gases.
3. Segregate activities of personnel.
4. Provide underwater protection by means of tanks and voids.

5. Strengthen the structure of the ship.

Compartments are designated and identified by SYMBOLS which are made up of LETTERS and NUMBERS. Each compartment has its own symbol, which is stencilled on the bulkhead, hatch, or door. Port compartments have EVEN numbers. STARBOARD compartments carry ODD numbers.

The first letter of the symbol is always either A, B, or C, (and D in older ships). A indicates a compartment located FORWARD of the machinery space; B refers to AMIDSHIPS or machinery spaces; and C means the compartment is AFT of the machinery spaces. In older ships the B and C compartments are in the machinery spaces; D compartments are aft of the machinery spaces. The divisions of a new (three-division) ship are indicated in the upper diagram of figure 360. The lower diagram represents the way a new series of compartment numbers begins at the forward end of each division, with the even numbers on the port side and the odd numbers starboard.

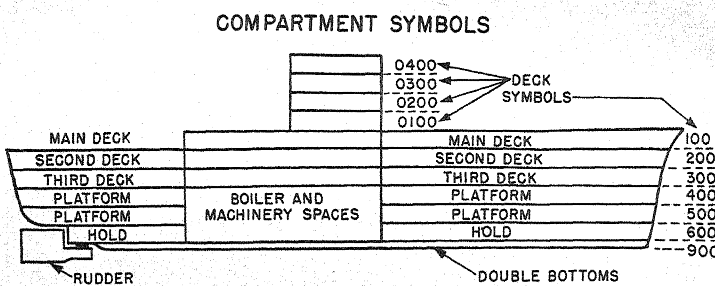


Figure 361.— Compartment-deck numbers.

After the division letter, the deck designation comes next in the symbol. Main deck compartments are indicated by numbers, such as 102,109, or 117. Second deck compartments are indicated by numbers from 201 through 299, and third deck numbers begin at 301. A zero preceding the number indicates a location above the main deck (see figure 361). The double bottoms always form a 900 series on any ship regardless of the number of decks above.

The use of a compartment is indicated by a letter which

FOLLOWS the symbol number. The letters and their meanings are—

A—Supply and storage.	*L*—Living quarters.
C—Control.	*M*—Ammunition.
E—Machinery.	*T*—Trunks and passages.
F—Fuel.	*V*—Voids.
	W—Water.

Here's a sample of a compartment symbol.

C—2 17 *A*

- *A* — supply compartment.
- 17 — compartment number (starboard side).
- 2 — second deck.
- *C* — after part of ship (C division).

Learn this standard compartment symbol system. It's used on all ships except a few of the older ones which have the additional subdivision D. When you are ordered to go to a designated compartment you must be able to get there with a minimum of confusion and delay. KNOW WHERE YOU ARE GOING.

WATERTIGHT CLOSURES

WATERTIGHT DOORS (WT) are doors used in watertight bulkheads. They are designed to resist as much pressure as the bulkheads through which they give access. All watertight doors are secured with a mechanical device known as a dog. Usually a watertight door has ten individually operated dogs; however, some are equipped with a handwheel which operates all the dogs at once and these are known as QUICK-ACTING WATERTIGHT DOORS.

HATCHES are horizontal doors which are used for access through decks. A hatch is either set with its top surface flush with the deck or on a coaming raised above the deck. Hatches do not operate with quick-acting devices but must be secured with individually operated dogs.

ESCAPE SCUTTLES are round openings with quick-acting closures which are placed in hatches. Such a scuttle may also be placed in the deck itself, in a compartment which has only one hatch.

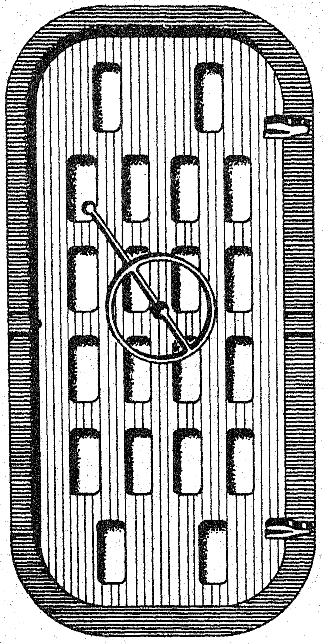


Figure 362.— Quick-acting WT door.

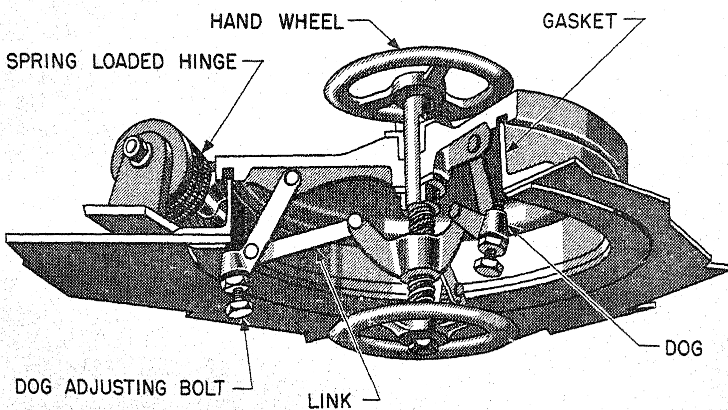


Figure 363.— Escape scuttle in hatch cover.

MANHOLES of the hinged type are really miniature hatches which are provided in decks and bulkheads for occasional access to water and fuel tanks and voids. Bolted manholes are sections of plate which are gasketed and bolted over deck-access openings. They are placed in the deck "just in case" access may be required but are seldom opened by ship's personnel except for periodic inspections.

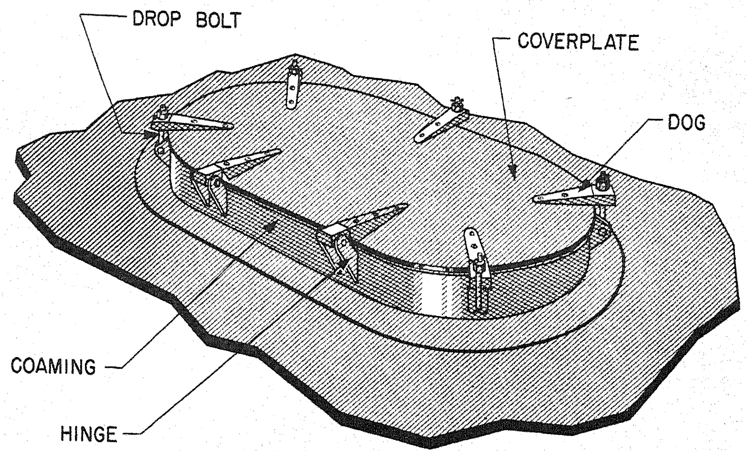


Figure 364.—Hinged manhole.

Most access-closure devices depend for their tightness on a rubber gasket which is usually mounted in the covering part to close against a fixed-position knife edge. Gaskets of this type are either pressed into a groove or secured with retaining strips held in place with screws or bolts.

CARE OF CLOSURE FITTINGS AND GASKETS

Rubber gaskets used with closure fittings should never be painted and they must be kept free of dirt and grease. Knife edges should be kept bright and smooth, free of dust, grease, and paint. Never use abrasives on knife edges.

Dogs and pins should not be removed for cleaning but may be removed by qualified personnel for adjustment or repair. Steel bolts should be kept clean and slushed with a light coating of

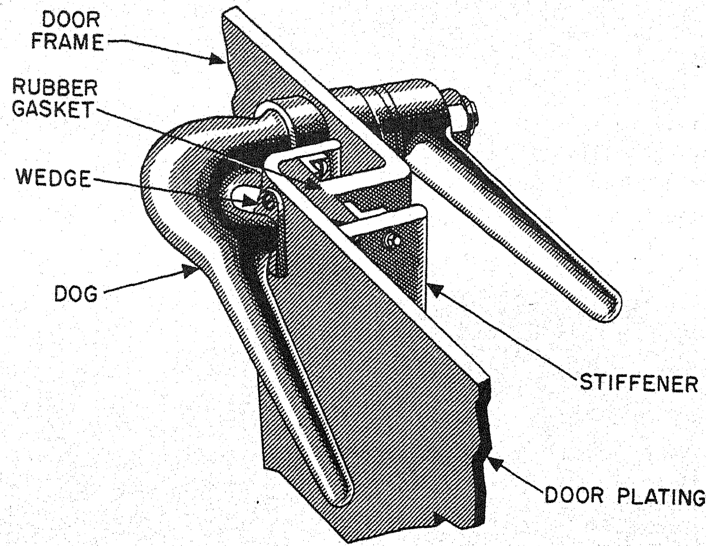


Figure 365.—How dog and gasket are used in securing WT doors.

heavy grease. Corrosion-resisting alloy bolts require only an occasional wiping with an oily rag.

WT doors and hatches will retain their efficiency longer and require less maintenance if they are properly closed and opened. When you close a door first set up a dog that is OPPOSITE the hinges with just enough pressure to keep the door shut. Then set up the other dogs evenly to obtain uniform bearing all around. When you open a door, start with a dog NEAREST the hinges. This procedure will keep the door from springing and make it easier to operate the remaining dogs. Don't pound on the dogs to tighten them—use a wrench, which is just a piece of pipe about a foot long and which is kept near the door. When dogged closures are defective they can often be repaired simply by adjusting the individual dogs. After you get a door properly adjusted, check to be sure that you have replaced all of the parts.

If a knife edge does not bear evenly against its gasket, temporary repair may be made by removing the gasket and building up behind it with wood, cardboard, or metal shims. The wedge

against which a dog bears may also be built up with shims. If the knife edge itself is unevenly worn or has corroded so that its bearing surface has been destroyed, the only satisfactory permanent repair is to build up the knife edge with welding, and then dress the built-up surface.

AIRPORT COVERS AND LENSES

You may be required to set up the dogs on airport covers which operate much the same as doors and hatches. There is this additional danger, however. If the dogs are allowed to become loose, the lens may be broken by a heavy sea or by the working of the ship in a seaway.

In hinging up airport covers, be sure to bring the hinge pin of the cover all the way out to the end of the hinge, to avoid breaking the cover.

In renewing lenses, remove the old lens and clean the threads of the frame and the retaining ring. If the frame and the ring are of composition, apply a light coat of oil or grease to the threads. Insert a new lens, imbed it in white lead, putty, or other approved material, and secure the retaining ring. This should force the putty out evenly all around to insure a tight fit.

SELECTION AND APPLICATION OF GASKETS AND PACKING

For the more common type of doors, hatches, and similar openings, material for sheet-rubber and strip gaskets will be on hand for issue by the supply department. For special gaskets and packings refer to General Specifications, Appendix 9—Gaskets and Packings, which prescribes the correct gaskets and packings for all hull fittings. This publication refers to materials by Navy specifications numbers and those numbers are covered in separate leaflet specifications. Both publications will be on file in the Engineering Log Room.

When cutting a gasket, plan as few breaks or joints as possible. The fewer the joints, the stronger and more leakproof the seal. Clean the steel surface, cut the gasket to the desired length so that the butts will fit snugly, cement the new gasket

in place, and secure it with the retaining strips. If you are short on gasket material you may improve the seal by reversing the old gasket. It is better, however, if the material is available, to use new gasket material.

Gaskets for armored hatches are made up in straight and curved sections, so slight breaks are unavoidable. Cement is NOT used on armored hatch gaskets.

CHALK TESTS FOR CLOSURES

A simple way to test the knife edges and gasket on a door or other fitting is to chalk the bearing surface of the knife edge, and then close the fitting by the usual method. When you open it you'll find the chalk line marked on the gasket by the knife edge. Irregularities or breaks in the chalk lines indicate improper adjustment of dogs, a defective gasket, warped closure or frame, or worn places along the knife edge. Make adjustments or repairs and repeat the test until the chalk mark on the gasket is uniform and continuous.

VISUAL INSPECTION OF COMPARTMENTS

Periodic visual inspections are made of all watertight boundaries of a ship at least semiannually. This inspection is made by darkening the compartment to be inspected and then lighting up all adjacent compartments.

Inspection of the compartment from the darkened interior will disclose any serious defects.

A check-off list of all fittings—doors, hatches, manholes, deck drains and valves, piping, ventilation closures and ducts, and stuffing glands—is issued to inspecting personnel and any defects affecting watertight integrity are noted. Any defect discovered in the boundaries or watertight fittings of a compartment makes that compartment unsatisfactory' and repairs must be made as soon as possible.

Visual inspection is particularly for those compartments which cannot be air-tested. These spaces include fire rooms, uptake enclosures, chain lockers, engine rooms and main motor rooms, and other machinery spaces.

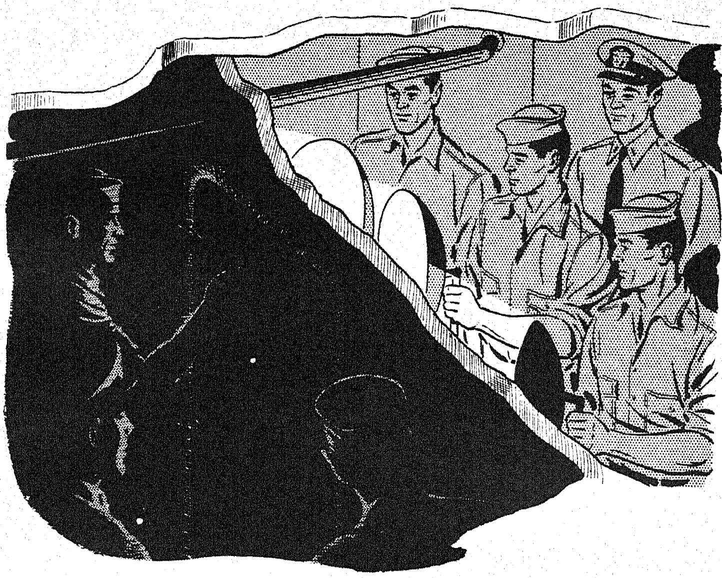


Figure 366. — Visual inspection tests.

AIR TESTING

When a ship is on the building ways, each watertight compartment, void, and tank is tested by filling it with water which is put under the pressure provided in the design specifications for that compartment. Of course, this method is impracticable when the ship is in operation, so an AIR TEST is substituted for the water test.

For the air test, all fittings of the compartment are closed or blanked off. Then the air-testing equipment is connected to the air-test fitting, usually a short nipple welded or threaded into a hole in the bulkhead, deck, manhole cover, or door.

The air-testing equipment is usually operated by a crew of three or more. Each testing set consists of a base on which is mounted a reducing valve with readings from ¼ pound to 5 pounds, an intake reducing valve, a relief valve, a mercury gage and sufficient air hose to reach a low-pressure air connection.

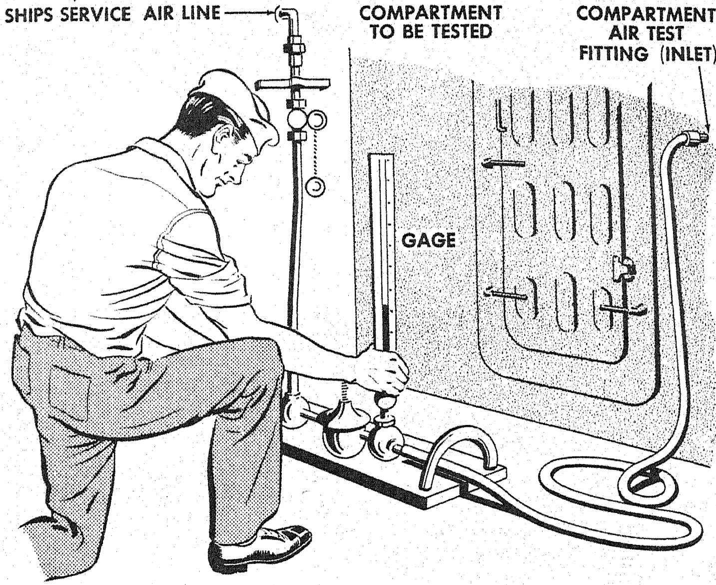


Figure 367.—Air-testing a compartment.

The mercury gage may be permanently attached to t... boun-... may be provided separately. But be sure you use a mercu... gage—a spring gage is not sufficiently dependable.

When the equipment is set up, the intake reducing valve is regulated to provide the exact pressure that has been specifie... for the test for that compartment. The pressure specified will depend on the location and construction of the compartment being tested. Under no condition should the specified pressure be exceeded, because excessive pressure might damage fittings and boundaries.

As soon as the specified pressure of the compartment is reached, the air supply is closed. The mercury gage is then observed for a period of 10 minutes for a drop in pressure. The results of the test are then recorded on an AIR TEST RECORD sheet. These records are recorded in the hull book ar... tually included in the quarterly report of WATERTIGHT INTEGRITY AND AIR TESTS.

If the compartment doesn't pass the test, the easiest method for locating the leak is to apply a soapsuds solution around all manhole covers, doors, and other possible sources of leaks. When the leak is determined, if it's a minor job you may repair it by inserting shims or other on-the-job expedients. If it's a major job it may call for welding.

After the leak has been repaired, another air test must be made. Sometimes it may be necessary to make several tests before the compartment passes the test.

DAMAGE CONTROL

Damage control means doing anything that can be done to—

1. Preserve the watertight integrity of the ship.
2. Maintain the buoyancy, stability, fire-power, and maneuverability of the ship.
3. Make rapid repairs to damaged gear and structure.
4. Furnish fire protection and extinguish fires.

Damage control is a serious and important matter. It deserves your most serious thoughts and efforts, for it is through [illegible]t in a damage control party that you can contribute [illegible] to keeping your ship afloat and under way.

When a ship is commissioned, some of the crew members are immediately organized into damage control parties. The num-[illegible] of such parties depends on the size and type of ship, damage control equipment and facilities provided, and the number of men available for assignment. A destroyer will probably have only three parties. A battleship usually has six, designated this way—

Station Designation	Location
Repair I	Main deck (and above) repair.
Repair II	Forward repair.
Repair III	After repair.
[illegible]pair IV	Amidship repair.
Repair V	Engineering repair.
Repair V[illegible]	[illegible]dnance repair.

Aircraft carriers usually have two additional repair parties—

Repair VII——	Gasoline stowage and repair.
Repair VIII——	Flight deck repair (for aircraft carriers only. On Escort aircraft carriers the functions of Repair VII and Repair VIII are combined with those of Repair I.)

Each damage control party contains a number of different ratings. This organization provides skilled men for any type of work and decreases the likelihood of all men of one rate being wiped out by a single hit. For example, if assigned to Repair V you'll find that this party will include a Damage Controlman, Machinist's Mates, Metalsmiths, Electrician's Mates, and Boilermen.

You, or one of your group, may be assigned as a JZ telephone talker, messenger, oxygen-breathing man or his tender. You'll need a knowledge of first aid. There'll be a Hospital Corpsman in the damage control party with you, but he may not be in the same spot you are when first aid to a shipmate is needed.

The officer in charge of your party may be one of the assistant damage control officers, or he may be your own division officer. His assistant will be a chief or first class petty officer.

The officer in charge of your party, who works directly under the Damage Control Officer, is responsible for training all of the members of the repair party in all of the duties of damage control.

You'll be trained as a talker, messenger, or an oxygen-breathing man just in case you have to pick up one of these jobs in addition to the specialty of your rating. Your job is to learn all of these duties thoroughly.

A good sailor knows his ship—the whole ship, not just the part in which he is assigned. In an emergency you may have to work anywhere on the ship, depending on the location and extent of damage.

Be able to find your way to any compartment in the dark, and be able to close any valves, doors, or hatches by feel alone. If you can do that you will be an effective man in any repair party.

DAMAGE CONTROL SYSTEMS

Know the important Damage Control Systems—

1. Drainage and Flooding.
2. Firemain and Sprinkling.
3. Ventilation.
4. Fuel Oil, Fresh Water, and Ballast.
5. Compressed Air.
6. Communication.

In addition to knowing these systems, know your own assigned job perfectly. You can get information on these systems from your ship's *Damage Control Book*, *Damage Control Bill*, and *Casualty Control Bill*. You will learn a lot from drills and practical experience. Danger may appear at any time—BE PREPARED.

Drainage and Flooding System

The purposes of the drainage and flooding equipment are—

1. To remove large amounts of water from compartments and spaces after battle or other damage.
2. To remove water from the hull under normal operating conditions.
3. To flood compartments to improve trim and stability of the ship.

There are three principal types of fixed mechanical drainage systems—MAIN DRAINAGE, SECONDARY DRAINAGE, and MAIN CONDENSER CIRCULATING PUMPS.

THE MAIN DRAINAGE SYSTEM is designed to remove water accumulated in bilges by ordinary seepage and to remove water shipped by reason of damage or accident. It is made up of piping and pumps that can move large quantities of water in a short time. This is necessary in draining large spaces such as the engine rooms and the fire rooms. Usually the piping is a fore-and-aft line running alongside the keel through the central section of the ship. Smaller branches and take-offs reach bilge-wells, tanks, and other compartments. Locate the valves, learn their purpose, and learn how to operate them.

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THE SECONDARY DRAINAGE SYSTEMS serve the same purpose as the main drainage system except that they are located in different sections of the ship. In some ships such as the DD 692 Class there will be a portion of the secondary drainage system located in the bow and another in the stern of the ship. The capacity of this system is small compared to that of the main system. It usually consists of one fore-and-aft line with branches to the compartments.

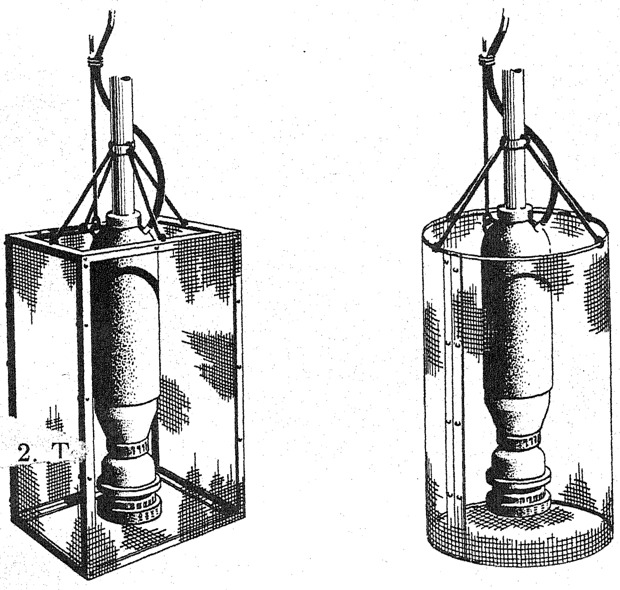
THE MAIN CONDENSER CIRCULATING PUMPS can be used for emergency drainage of the engine rooms. These are large-capacity pumps (usually centrifugal), the normal job of which is to circulate water from the sea to the main condenser in the engine or machinery rooms and discharge it overboard again. Each pump, however, has a secondary bilge suction from the engine room in which it is located, and the pump can drain this space in an emergency. No other space can be drained by this type of pump unless, by accident or design, another space should drain into the engine room where the pump is located.

In addition to the three fixed mechanical drainage systems, there is a system of drainage by gravity and there are also various items of portable equipment for drainage. Spa[illegible] the waterline (deck drains in compartments, washroo[illegible], [illegible], and heads) are drained overboard by gravity. In some exceptional cases, spaces at or near the waterline drain by gravity into a bilge-well or other lower space, from which water may be pumped overboard by the main or secondary drainage system. Permanently installed eductor drain systems may also be used for compartments just below the water line. The main types of portable equipment for drainage are—portable electric submersible pumps, gasoline handy bill pumps, portable water jet pumps (eductors), and hand pumps. The operation of all of these pumps except the submersible pump will be explained in the section of this chapter concerned with fire fighting.

THE PORTABLE ELECTRIC SUBMERSIBLE PUMP is used for removing water from flooded compartments. If the strainer is kept clean and the discharge head kept low, this pump can move 180 gallons per minute.

The efficiency of the pump is improved if a BASKET STRAINER

is used in addition to the standard suction strainer that comes with the pump. You can make up these baskets of No. 3 mesh (0.054-inch wire) screen stock, which is available under Navy Specification No. 42-C-21596. Baskets must be used with all types of pumps and eductors when flood water is being pumped.



SQUARE STRAINER BASKET   ROUND STRAINER BASKET

Figure 368.—Portable electric submersible pump with basket strainers.

Submersible pumps should be lowered, raised, and secured (while pumping) only by the handling line. This line is secured to the pump housing through an eye attached for that purpose. Never lower or raise the pump by the electric cable. This will break the watertight seal where the cable enters the housing. The handling line may be married to the cable, provided considerable slack is left in the cable.

To secure a higher lift, two submersible pumps may be connected in tandem. A multiple outlet box is provided (or should

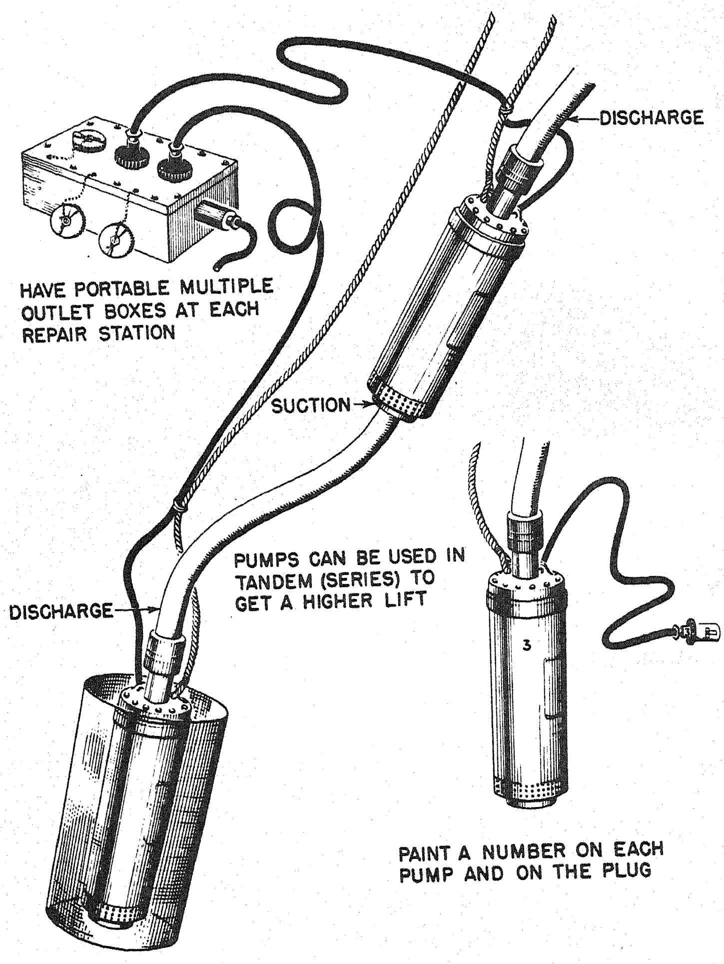


Figure 369.—Tandem connections for submersible pumps.

be constructed on board ship) for making the necessary electrical connections.

Keep in mind the following precautions when placing a submersible pump in operation or in actual use:

1. Keep handling line, electric cable, and discharge hose clear so that the pump can be removed quickly.
2. Keep hose free of kinks for maximum output.
3. Always use a strainer.
4. Keep the strainer clean at all times, using a wire brush.
5. Keep suction lift and discharge head as low as possible.
6. Keep the suction end of the pump or the end of the suction hose in the water while the motor is in operation.
7. Above all, IF GASOLINE FUMES ARE PRESENT, NEVER USE AN ELECTRIC SUBMERSIBLE PUMP or any other apparatus that might produce a spark.

Firemain and Sprinkling Systems

The firemain system is made up of piping, pumps, plugs, valves, and controls. This system is designed to supply ample water for fire fighting, sprinkling magazines, swabbing down, and for any other purpose for which salt water is normally used.

The piping may be a straight line or a loop system. The latter is found on larger ships. Risers go from the firemain to fire plugs on the upper deck levels. The firemain system is so designed that any damaged section of piping can be isolated from the system. Study the firemain system by following the piping from stem to stern, deck by deck, and compartment by compartment. Supplement this information by studying—

1. Blueprints and diagrams of the firemain system.
2. The General Information Book.
3. The Damage Control Firemain Operating Bill.
4. The Engineering Casualty Control Book.

By studying the firemain system as outlined you can learn to isolate damaged sections and thus restore pressure to the rest of the system.

Ventilation Systems

The ventilation systems aboard ship supply fresh air and remove stale air and gases, but they can be a source of danger

by flooding if damage control parties are careless. Ships have sufficient blowers to force fresh air through all compartments and through spaces below the waterline that are designed for ventilation.

The ventilation system helps to prevent fires and explosions by preventing the accumulation of explosive gases.

Fuel and Fresh Water Systems

Fuel and fresh-water systems consists of tanks, filling lines, and feed lines. These are important in damage control because the list and trim of the ship can be partially controlled by shifting the contents of the tanks. This method of balancing is better than flooding when the damage is below the waterline. A ship's "oil king" works with the Engineer Officer by direction of the Damage Control Officer on damage control problems that involve the transfer of tank contents.

Compressed-Air Systems

There are three compressed air systems: The high-pressure system, the low-pressure or the ship's service system, and the gas-ejecting system.

The HIGH-PRESSURE SYSTEM furnishes compressed air for torpedo charging and gun mount counter recoil charging as well as for the torpedo and ordnance workshop. Also on some ships the high-pressure system is an essential part of the gas-ejecting system, air from the compressors being necessary to supplement the air banks and low-pressure compressors when all guns are firing in order to maintain adequate gas-ejection air. On some ships it also furnishes air for catapults for launching planes.

The LOW-PRESSURE SYSTEM supplies air for general service and compartment testing.

The GAS-EJECTING SYSTEM is designed to furnish gas-ejecting air to the gun mounts at a rate sufficient to maintain continuous firing until the supply is exhausted.

Since compressed air also powers pneumatic tools used in damage control and in maintenance work it is well to be familiar with the systems, their purposes and their operation.

Communication System

When a ship is in action, the communication system is of vital importance. Control stations must be notified as to—

1. Location of casualties.
2. Extent of damage.
3. Corrective measures taken.
4. Progress being made.

As a member of a damage control party, you must be familiar with the various means of communication. These include—

1. Battle telephone circuits (sound-powered telephones).
2. Emergency sound-powered telephone circuits.
3. Damage control announcing system.
4. Ship's service telephones.
5. General announcing system.
6. Messengers.

The most important means of communication is the battle telephone circuit. All the others are auxiliary or emergency means of communication. Know where JACK BOXES are located and what systems and circuits they serve.

Learn the following circuits, and give particular attention to those that are included in your ships battle bill.

1. 2JZ Damage and stability control.
2. 3JZ Upper deck repair.
3. 4JZ Forward repair.
4. 5JZ After repair.
5. 6JZ Amidship repair.
6. 7JZ Engineer's repair.
7. 8JZ Flight deck repair.
8. 9JZ Magazine sprinkling and ordnance repair forward.
9. 10JZ Magazine sprinkling and ordnance repair aft.
10. 11JZ Superstructure repair.
11. X2JZ Damage and stability control, auxiliary control, auxiliary circuit.
12. X40J Casualty communication circuit.
13. 3JG Aircraft service.
14. 5JG Aviation ordnance.

15. 7JG Conflagration control.
16. JA Captain's battle circuit.
17. 1JV Maneuvering, docking, and catapult control.
18. 2JV Engineer's (main engines).
19. 3JV Engineer's (boilers).
20. 4JV Engineer's (fuel and stability).
21. 5JV Engineer's (electrical).
22. JL Lookouts (surface and sky).

In some instances the DAMAGE CONTROL ANNOUNCING SYSTEM (4MC) and the GENERAL ANNOUNCING SYSTEM (1MC) are used for damage control communication. Units located at various stations serve both as microphones and speakers. An advantage of this system is that orders or information can be heard by all hands present, thus eliminating possible error by the station's talker. The system is dependent, however, upon the ship's electrical circuit for power and is, therefore, more subject to battle damage than are the sound-powered circuits.

MATERIAL CONDITIONS

Navy vessels maintain different material conditions according to whether contact with the enemy is improbable, probable, or imminent. Each condition represents a different degree of tightness; the ship may be fairly well opened up when there is little danger of damage, but it will be closed up as much as possible when the danger is great and immediate. All doors, hatches, valves, and other fittings of damage control value are classified and marked, and these designations tell what fittings must be closed for each material condition.

Battleships, large carriers, and heavy cruisers have three material conditions—X-ray, Yoke, and Zebra; smaller ships may have only two—Able and Baker. Here is the material condition picture in table form.

CONDITION		DAMAGE IS—	CLOSE FITTINGS MARKED—
Larger Ships	Smaller Ships		
X-RAY		Improbable	X.
YOKE	BAKER	Probable	X and Y.
ZEBRA	ABLE	Imminent	X, Y, and Z.

Some doors, hatches, and valves must be left open during battle, and they are designated W (William).

COMPARTMENT CHECK-OFF LISTS

The compartment check-off list is an itemized list of all hatches, doors, valves, and other classified fittings that are used in damage control for setting up material conditions. It shows the name, location, purpose, and classification of each fitting and states who is responsible for its proper operation. An appropriate list is permanently posted in each compartment. A master copy of each list is kept in the damage control office. You must know the check-off list for each compartment in your assigned zone.

DAMAGE REPAIR

Repairs in action are strictly emergency. You'll have to use whatever material is at hand. Think and improvise. Remember—the important thing is to KEEP THE SHIP AFLOAT.

Battle damage you'll have to worry about includes hull ruptures, punctured bulkheads, flooded machinery spaces, warped doors, ruptured decks, leading pipes, weakened structures, and wreckage which interferes with the ship's functions. Many other types of damage too numerous to mention will be encountered. Just remember that in combat, personnel casualties could occur that would leave you in charge of a damage control party. Take every opportunity to learn damage control.

HOLES AND PATCHES

Small holes in the underwater hull result from near miss bombs or violent explosions in other parts of the ship.

Temporary repairs may be made by driving wooden plugs or wedges into small holes. Use bare, soft wood because it soaks up water, swells, and holds the plug or wedge firmly in place. Painted wood will not do this.

If you wrap the plugs with cloth you'll get an additional seal. Oakum may be driven into the blank spaces between the plugs. Square end plugs hold better than conical-shaped plugs.

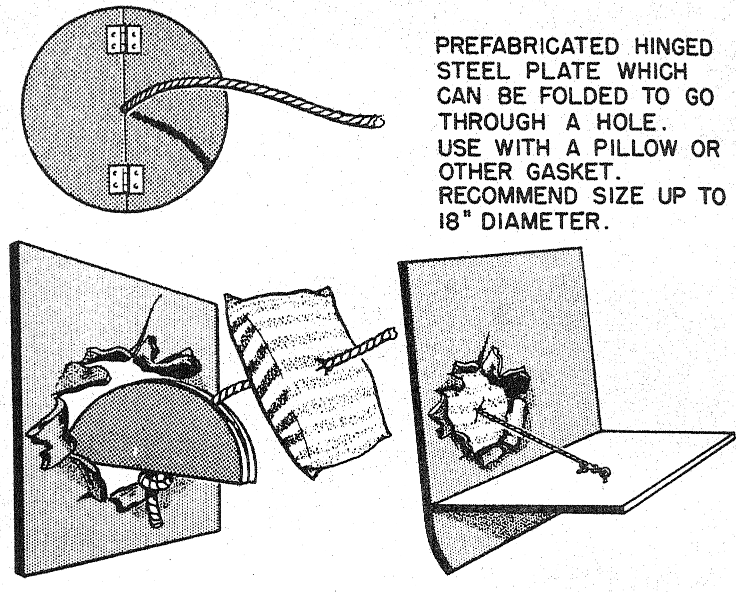


Figure 370.— Folding plate patch.

Wedges should not be driven into cracks because they will cause the cracks to enlarge and expand. Before you try to fill a crack, drill a small hole at each end of the crack. Plug these holes with wood or with machine screws. Then lay a flat piece of rubber or canvas over the crack, back it up with a board, and hold the patch in place with shoring. This type of patch must be inspected frequently, as it tends to shift and slip as the ship works.

Large holes through which water is pouring are difficult to control. The only control may be to isolate the damage and confine it to as small an area as possible.

Hull holes above the waterline may be more dangerous than they look. When the ship rolls these holes may admit water into spaces above the center of gravity and reduce the stability of the ship. Holes like this are given high priority. They are not difficult to patch. Either inside or outside patches may be used on them. Inside patches may be made with pillows and

mattresses, backed up with boards or mess table tops, and shored in place.

A good outside patch can be made with a pillow or mattress which has a hole punched in the center, like the one in figure 370. The back-up board must also have a hole in the center. A stout line is passed through the padding and board and knotted securely behind the board. The entire patch is then placed on the outside of the hole, the line being passed through the hole.

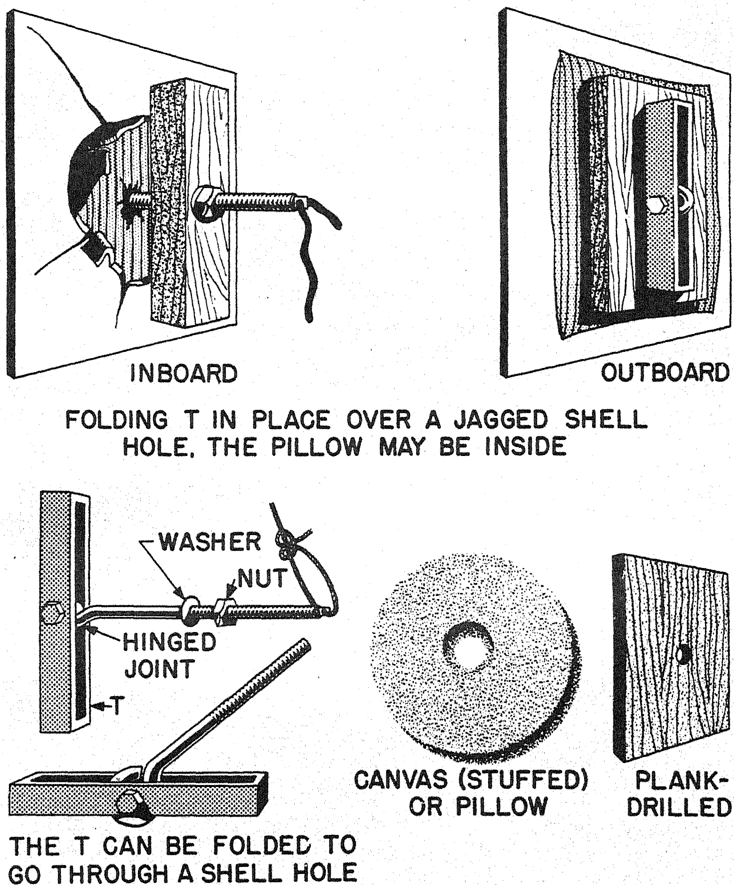


Figure 371.—Folding T-bolt patches.

and secured to a stanchion on the inside. The line can be tightened with a Spanish windlass.

A special prefabricated folding **T**-bolt patch has been developed for use over relatively small holes. The stock of the **T** is threaded and fitted with a washer and nut. A board and a pillow, each with a hole in the center, slide over the stock. The assembly can be folded, pushed through the hole, and tightened on the inside.

A simple type of patch you can make for large holes is just a steel plate with a hole drilled through the center. A knotted rope is passed through the hole and used to secure the patch when it is installed. A pad-eye with a long handling line should be installed on the edge of the patch for lowering it on the outside of the hull. The handling line is also used to support the patch after installation. A rubber gasket forms a seal between the patch and the hull. One vessel reported that it returned to base with 84 of these patches in place. Sizes up to five feet in diameter have been used with success.

Another patch, especially suitable for holes with jagged edges sticking inboard, is a miniature cofferdam or open box. It may be made of either wood or metal. The wooden version is usually 18 inches square and 6 inches deep. It can be shaped to fit the

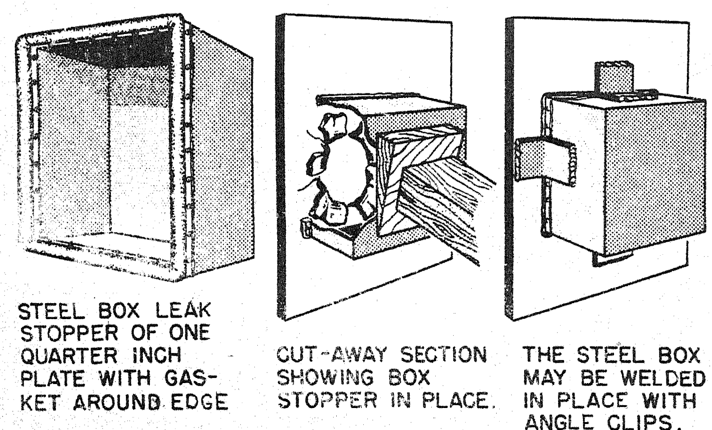


Figure 372. — Box patches.

contour of the hull, fitted with a rubber gasket, placed over the hole, and shored in place. The steel boxes are welded with angle clips.

As a result of bomb or collision shock, or structural distortion, a variety of small leaks may appear. These occur around tubes, piping, and loose rivets, and where angle irons have been pulled from decks and bulkheads. Many leaks of this kind can be repaired permanently as soon as they are reported.

Some minor leaks can be stopped by driving lead slugs, wires, or plugs into them. Plugs cut from sheet lead are effective in stopping leaks where plate has pulled loose from its rivets. Avoid welding a damaged riveted joint. The heat of welding may tend to spread the trouble to a larger area.

Rivets and bolts can be used to fill small holes if you have access to both sides of the bulkhead. Machine screws can be tapped into small holes which are accessible from only one side.

STRENGTH MEMBERS

Beams, frames, decks, and most bulkheads are strength members of the hull structures. If they give way or become weakened, the hull may collapse or break. Small vessels may not have the necessary equipment for extensive repairs. Some help can be afforded by shifting weights and by shoring.

Larger ships will have suitable equipment and stores for making extensive repairs. Beams and frames can be patched and strengthened by bolting and welding reinforcing bars and plates along the webs.

SHORING

Shoring is the bracing of members (or patches) so they will withstand excessive pressure. Most shoring is done with 4 x 4 timbers. In emergency, such gear as mess tables, lengths of piping, and steel bars are used. Some ships carry adjustable, telescoping shores. Others have angle bar shores which can be tack-welded in place.

It's improbable that any two shoring jobs will ever be handled in the same manner. Common sense and good judgment are essential.

Use the following principles as guides:

1. Bulkheads should be shored to decks, to beams overhead, or against stanchions and hatch combings. It is important to allow a three-point distribution of forces.
2. Exert every effort to avoid damage to flanges, bulkhead stiffeners, or deck beams. Too much pressure may cause damage to other bulkheads and decks.
3. Avoid breaking calked seals.
4. Use unpainted wedges and don't force them too much. If decks are oily, sprinkle dry sand under the wedges.
5. Place shores so that the pressure they receive will produce direct compression and not cross-axial pressure.
6. Do not place a shore under such great compression that it will bow. Instead, install several shores at close intervals.
7. Look sharp when a shore under compression begins to bow. It may snap at any time.
8. Use nails and cleats to lock a shore in position if there is any danger of its jumping out as the ship works.
9. Distribute the pressure on a bulkhead or deck over a wide area by use of strongbacks.
10. Back up each strongback with a number of shores against undamaged strength members of the ship's structure, suc as hatches, stanchions, machinery foundations, or frames.
11. If the pressure on a deck or bulkhead is so great that the next deck or bulkhead (used as an anchorage) cannot safely absorb all the pressure, carry the shoring along to the next deck or bulkhead, or even farther if necessary.
12. Use chainfalls, blocks and tackle, or jacks to move heavy weights back into their original position.

Learn what tools are available in the shoring chests and repair lockers and be sure you know how to use them.

ENTERING CLOSED COMPARTMENTS

Watertight doors, hatches, manholes, and scuttles should be opened only after you have made sure that the compartment is dry or so little flooded that no further flooding will be produced

by opening the closure. Extreme caution must be observed in opening closures below the waterline in the vicinity of the damage.

If the compartment to be entered is provided with a sounding tube, back off slowly on the cap or plug to the tube. If there is a rush of air around the threads while the cap is still under control, resecure the cap. The rush of air indicates that the compartment is being flooded. To permit the air to escape would allow more water to enter the compartment. If water trickles out around the threads while the cap is still under control, resecure the cap. This indicates that the compartment is completely flooded. To remove the cap would produce flooding of an upper compartment with possibly serious consequences. Report all flooded compartments as soon as they are discovered.

Many compartments are not provided with a sounding tube. Tapping on the bulkhead with a hammer at various levels will often disclose the exact height to which a compartment has become flooded. You should occasionally tap a bulkhead for practice to become familiar with the sound of an empty compartment.

Another method is to back off on the air-test cap. The same precautions should be followed as in the case of opening a sounding tube. Do not lose control of the opening.

If the compartment contains drain lines, you can test the space by suction on the lines. If water shows at the pump discharge, the compartment is flooded. If the check valve rattles, the compartment is dry. When using this method, make sure the drain suction line is not ruptured between the pump and the compartment being investigated.

Sometimes it becomes necessary to test a compartment by backing off slowly on some of the dogs of a door or a hatch to the space in question. Slack up slightly on the dogs on the hinged side. If water is present, it will trickle between the gasket and the knife edges on that side. Control of the opening is still maintained by means of the hinges and the opposite dogs. Never loosen the dogs opposite the hinges first. If you make this mistake, excessive pressure on the other side of the bulk-

head may spring the door or throw it open, with the resultant rapid flooding of an additional compartment.

Before entering a closed compartment, you must make sure that the working atmosphere is safe. If your work in the compartment might cause a spark or flame, check the air with an explosimeter or hydrocarbon vapor indicator. You will thus be made aware if a dangerous concentration of explosive gases is present. Check the oxygen content of the air in the compartment by introducing a safety lamp. If the light burns without interruption, there is sufficient oxygen. Otherwise, oxygen breathing apparatus will be necessary, or it will be necessary to ventilate the compartment before entering.

WRECKAGE REMOVAL

Wreckage that interferes with the fighting efficiency of the ship must be cleared quickly. Loose wreckage may be removed by hand. Many pieces and objects will require cutting or

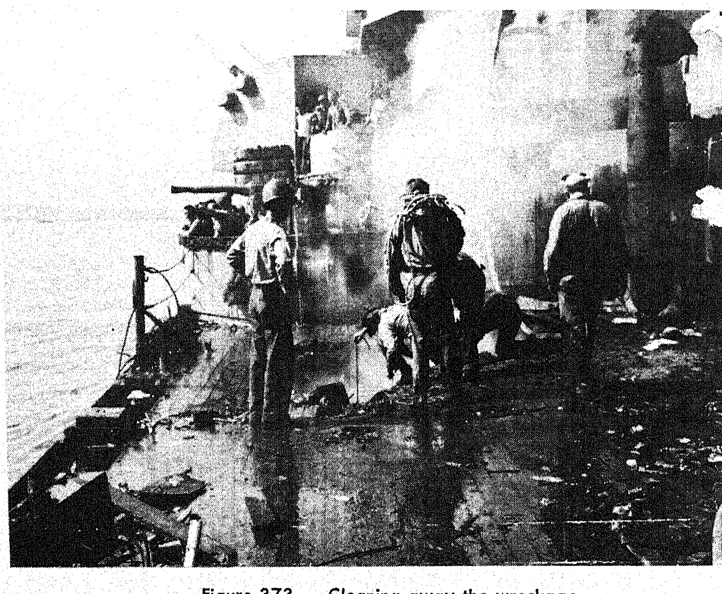


Figure 373.—Cleaning away the wreckage.

breaking. Power chisels, air hammers, and acetylene cutting equipment are best for clearing extensive damage. The use of cutting torches is discussed in the chapter on the cutting of metals. When power is OUT, it may be necessary to use mauls, sledges, axes, heavy cold chisels, rivet bars, and pinch bars.

Sometimes it's necessary to remove burning bedding, stores, and supplies. For this work a devil's-claw is handy. It is a rake with three steel claws and an 8-foot handle made of ¾-inch steel pipe.

Fire extinguishers, hose, and rescue gear should be kept at hand when you are clearing wreckage. If you don't play safe you may cause additional damage and loss of life.

KINDS OF FIRES

Different types of fires are combated by different means: water used in a SOLID STREAM or as a fine spray called FOG; a mechanical or chemical FOAM; a combination of fog and foam; CARBON DIOXIDE (CO_2); or STEAM. If you understand which of the above methods to use against a specific type of fire and the purpose behind it, you will be a valuable asset to the damage control gang.

Fires have been classified into three general types:

CLASS A fires are fires in ordinary combustible materials (such as bedding, clothing, wood, canvas, rope, and paper) where the cooling effect of water is of first importance in extinguishment. The chief characteristic of class A combustibles is the embers or ashes remaining after burning. Such material must be cooled throughout the entire mass before extinguishment is complete.

CLASS B fires are fires in inflammable liquids (such as gasoline, oil, grease, paint, and turpentine). Materials of this type burn at the surface where the vapors are given off, and a smothering or blanketing of the burning liquid is essential for extinguishment. Foam, CO_2, steam (in bilges), and a combined use of fog with foam are effective in smothering this type of fire.

CLASS C fires are fires in electrical equipment where

the use of a "non-conducting" extinguishing agent is of first importance. In most electrical fires it is necessary to de-energize the circuits before any progress can be made. Carbon dioxide (CO_2) is a non-conductor of electricity and will not damage electrical equipment. Water fog would be the second choice in extinguishing an electrical fire but may cause damage to the gear.

The following table shows the extinguishing agents used in fighting different kinds of fires. The agents are listed in the order of preferred use.

COMBUSTIBLE	CLASS FIRE	EXTENT	EXTINGUISHING AGENTS
Woodwork, bedding, clothes, combustible stores.	A	Small	Solid water stream. Low-velocity fog. High-velocity fog. Portable CO_2 extinguishers.
		Large	High-velocity fog. Low-velocity fog. Solid water stream. CO_2 (fixed system).
Films, celluloid, etc.	A		Water immersion. Solid water stream. High-velocity fog.
Explosives	A	Small	Water immersion. Magazine sprinkling. Solid water stream.
		Large	Water immersion. Magazine sprinkling and flooding. Solid water stream.
Incendiary bombs	A		(Throw overboard). High-velocity fog. Sand.
Gasoline	B	Small	Portable CO_2 extinguishers. Foam. Fog-foam. Low-velocity fog (to prevent spread). Installed fog spray (to prevent spread).

COMBUSTIBLE	CLASS FIRE	EXTENT	EXTINGUISHING AGENTS
Gasoline	B	Large	Foam. Fog-foam. Fog-spray. CO_2 (fixed system). High-velocity or low-velocity fog (to prevent spread). Installed sprinkling system (to prevent spread). Water curtains (to prevent spread).
Kerosene, fuel oil, and Diesel oil.	B	Small	Portable CO_2 extinguishers. Low-velocity or high-velocity fog. Foam.
		Large	Foam. Fog-foam. High-velocity fog. CO_2 (fixed system). Steam smothering.
Paints, spirits, inflammable stores.	B	Small	Portable CO_2 extinguishers. Low-velocity or high-velocity fog. Foam.
		Large	CO_2 (fixed system). High-velocity or low-velocity fog. Foam. Installed sprinkling system. Steam smothering.
Electrical and radio apparatus.	C	Small	(De-energize affected circuits). Portable CO_2 extinguishers. High-velocity fog.
		Large	(De-energize affected circuits). Portable CO_2 extinguishers or CO_2 hose reel system. High-velocity fog. Foam application.

FIRE-FIGHTING EQUIPMENT

The principal kinds of fire-fighting systems and equipment—some INSTALLED, some PORTABLE—include these:

Forcible entry tools.

Fire main system.

Navy all-purpose nozzles.

Foam equipment (mechanical and chemical).

Fog sprays.

CO_2 extinguishers (fixed piping, hose reel, and portable types).

Handy billy, P–500, and other pumps.

Steam smothering system (for bilges).

Oxygen breathing apparatus, hose (air-line) mask, and asbestos suits.

Do you know where this equipment is located? How it is operated? How it works? Why it works? If not—FIND OUT. It's your job to KNOW!

FIRE-MAIN SYSTEM

There are two couplings on each length of hose—a male coupling at one end and a female coupling at the other. Other couplings that you will use include double female couplings for connecting two male couplings or for making up jumper-line assemblies in repairing a damaged fire main; double male couplings for joining two female couplings; and increaser couplings

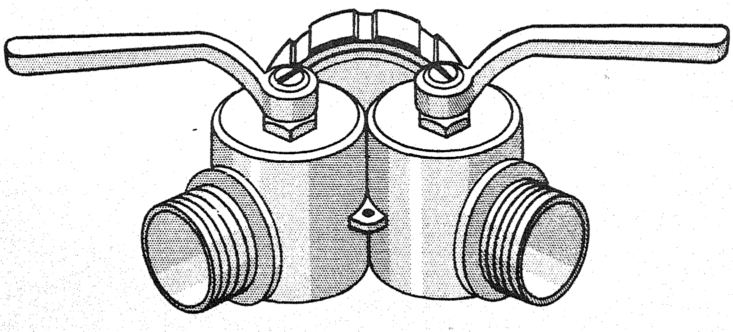


Figure 374.— Wye-gate.

for connecting the female end of a 2½-inch hose to a 1½-inch outlet.

Connected to fire plugs, and stored in adjacent racks, you will find two lengths of either 1½-inch or 2½-inch hose. (Only one length of hose is racked adjacent to fire plugs in machinery spaces.) The 1½-inch hose is used on smaller ships, and below decks on larger ships. This hose is made up in 50-foot lengths, with the necessary end couplings. All threaded parts of fire-hose fittings and couplings have standard threads and are easy to connect.

Two men working together can connect fire hose in a hurry. You can do the job alone if you place the hose on the deck and press it down with your foot just behind the coupling. The pressure of your foot will cause the metal coupling on the end of the hose to point upwards so that you can screw on the nozzle or other coupling.

To connect threaded parts, take a half-turn to the left to set the threads, and then turn to the right until the joint is tight. Be careful not to cross the threads. Final tightening with a spanner wrench is not necessary if the fittings and gaskets are maintained in proper working condition. A spanner wrench should be used, however, on suction hose.

Fire hose is usually faked on a bulkhead rack near a fire plug. Nozzles, applicators, and spanner wrenches are racked on the bulkhead near the hose.

When two lines are faked separately on the bulkhead, one is connected to the fire main and the other is left unconnected.

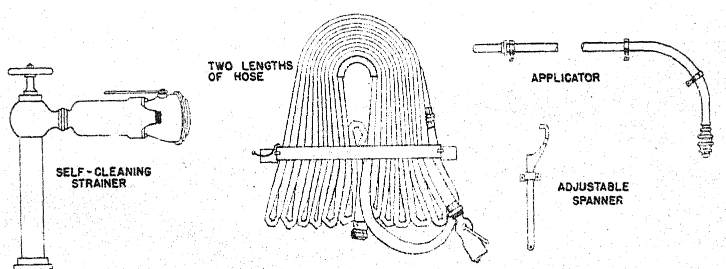


Figure 375.—Fire hose faked on a rack.

Always fake the lines with their ends hanging down so that they will be ready for instant use. The end of the line should be equipped with an all-purpose nozzle.

To stow a hose, lay it out straight, double the male end back until it reaches to within four feet of the female end, start rolling the hose at the fold, finish the roll, and secure it with a small line or strap. You will thus have the female end on the outside end and ready for connecting—the male end will be inside where its threads are protected.

ALL-PURPOSE FIRE NOZZLES

The Navy's all-purpose nozzle can produce either fog or a solid stream of water. This type of nozzle is available for both 1½- and 2½-inch hose. It can be adjusted or shut off quickly and easily by means of a lever.

Fog comes out through an opening in the lower part of the nozzle. When a straight stream is used the water shoots out of the upper part, above the fog outlet.

The all-purpose nozzle is usually set to produce a high-velocity

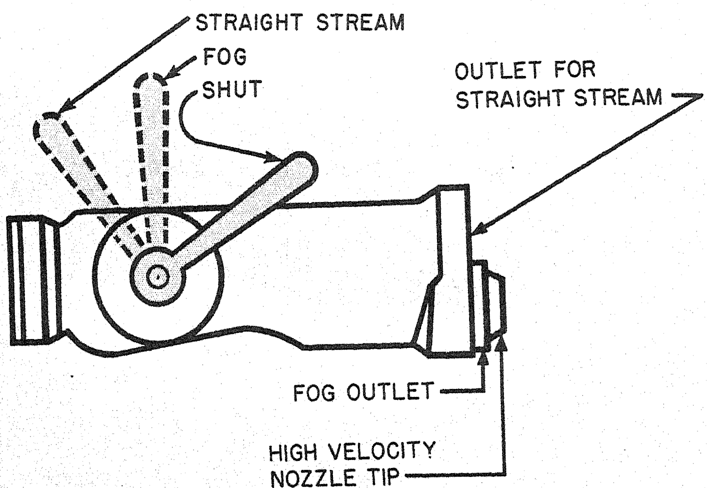


Figure 376.—All-purpose nozzle.

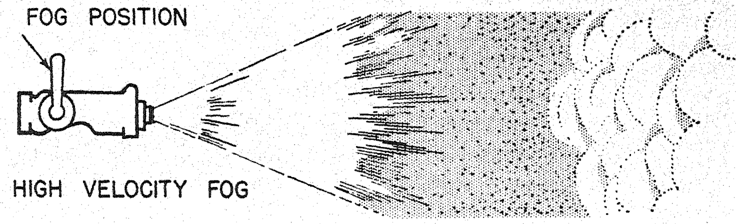


Figure 377.—High-velocity fog.

fog. For this use, a removable, high-velocity nozzle tip is installed in the fog outlet.

For a low-velocity fog, remove the high-velocity nozzle tip and replace it with an applicator equipped with a fog head. Three applicators are shown in figure 378. With this set-up you can still get a solid stream of water by pulling the nozzle control handle all the way back.

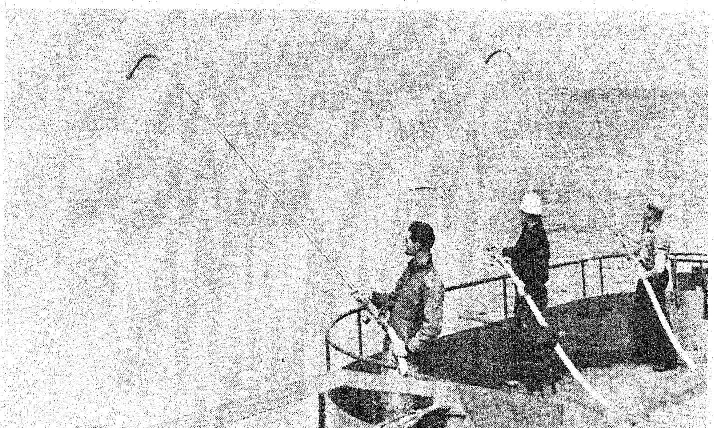


Figure 378—Standard applicators.

FOAM DEVICES

Foam fire-fighting devices generate either chemical or mechanical foam. Chemical foam is produced by mixing a powder and water in a hopper-type mixer. Mechanical foam is produced by

a liquid preparation which is mixed with water by means of the *S*-type proportioner on the handy billy, a pick-up tube on the nozzle, or in a duplex proportioner. In each case the foam is made with chemicals. The difference between the two types is that mechanical foam is created by adding air to water that contains foam liquid, while chemical foam is created by the reaction of the chemical powder to water.

Chemical foam is produced by the continuous-type foam generator, which consists of an open hopper with an ejector at the bottom. Fifty-pound containers of dry chemical foam mixture are emptied into the hopper, one after the other, as you fight a fire. A stream of salt or fresh water under pressure passes through the ejector, where it picks up the foam powder. From the ejector the stream of water containing chemicals passes through 2½-inch hose line that should be at least 100 feet, but not more than 150 feet, long for thorough mixing. The outlet end of the hose should be equipped with a nozzle that is 1¾ inches in diameter.

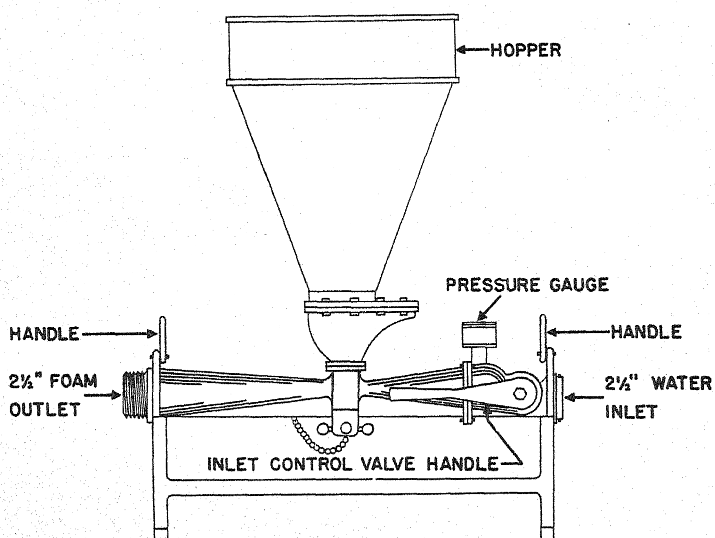


Figure 379.—Continuous-type foam generator.

The continuous-type generator uses approximately 100 pounds of foam chemical per minute, which makes about 800 gallons of chemical foam. The ejector is designed so that the passing stream of water will drain the proper quantity of foam chemical into the stream regardless of water pressure. The Navy also uses three portable devices which produce mechanical foam for fighting fires—

1. Duplex pressure proportioner (portable or installed).
2. Straight-type pick-up tube proportioner (portable with pick-up tube attached directly to mechanical foam nozzle.)
3. *S*-type proportioner (for use with gasoline-engine-driven handy billy pump).

Each of these devices uses a mechanical-foam nozzle. This nozzle has a 21-inch length of flexible metal or asbestos composition hose. It is two inches in diameter, has a solid metal nozzle outlet, and a suction chamber and airport in the butt

Figure 380.—Mechanical-foam nozzle and pick-up tube.

end. The foam that is discharged is a mixture of water, liquid-foam solution, and air.

One of the most common fire-fighting devices abroad ship is the duplex pressure proportioner. It is an installed or portable duplex cylinder which holds a mechanical-foam solution that is added in the proper proportion to the water stream.

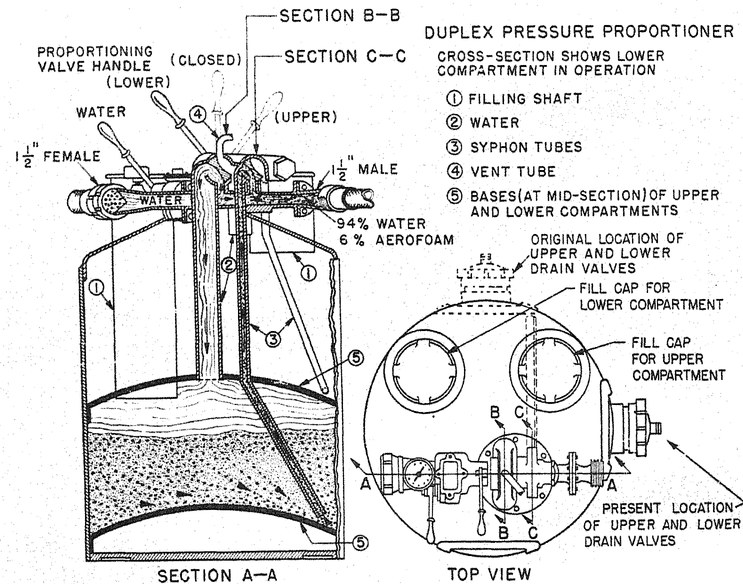


Figure 381.— Duplex pressure proportioner.

The other two mechanical-foam devices make use of a pick-up tube, which is a short piece of 5/8-inch pipe with a short length of

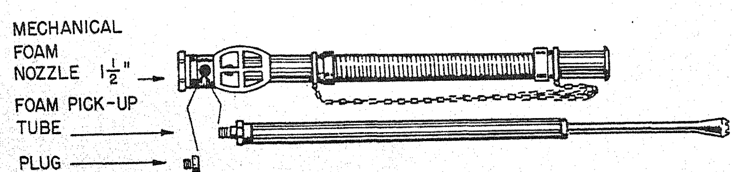


Figure 382.— Straight-type pick-up proportioner.

rubber hose on one end. Figure 382 shows the arrangement by which the pick-up is joined to the mechanical-foam nozzle in the straight-type pick-up tube proportioner.

The pick-up can also be used with a handy billy pump if it is attached properly. In this system (*S*-TYPE SUCTION PROPORTIONER) the foam liquid is drawn into the suction chamber of the handy billy and forced into the water stream.

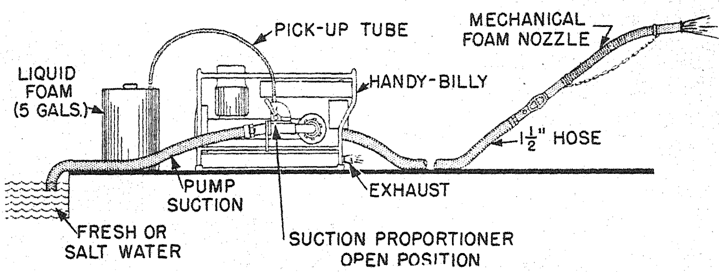


Figure 383.— S-type suction proportioner.

Aircraft carriers have been equipped with a HIGH-CAPACITY FOG-FOAM SYSTEM. This system consists of foam proportioners which inject foam liquid into auxiliary fire-main risers. The number of proportioners varies from 15 on the larger ships to 5 on the smallest. All of these proportioners have a capacity of 1,000 gallons per minute. The operation of the proportioner consists principally of the proper use of the control valve. This valve has three positions—OFF, PRIME, and FOAM. In the OFF position the proportioner acts as a water pump. In the PRIME position air is eliminated from the foam-liquid piping. In the FOAM position the suction of the foam pump is connected to the source of foam liquid, and its discharge is directed into the foam service-line riser, where it is mixed with the water.

SPRINKLING SYSTEMS

Sprinkling systems are installed in magazines, turrets, handling rooms, spaces where flammable materials are stowed, and, in some ships, in airplane hangar spaces. This system is con-

nected by hose lines to fire plugs of the fire main. The system is not usually automatic. If it is not automatic, valves must be operated by hand. In most cases, however, they can be operated at a distance by reach rods or by some power-driven mechanism.

FIXED FOG-SPRAY INSTALLATIONS

Fixed fog-spray installations are used aboard certain types of naval vessels—such as carriers, transports, and cargo ships—where there is great danger of gasoline fires.

The installation is made up of overhead fixed piping equipped with fog heads.

For operation, the system is connected with 2½-inch hose to a convenient fire plug. The system is not automatic.

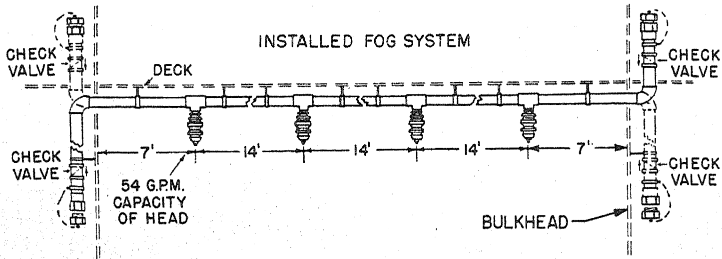


Figure 384.—Typical installed fog system.

CARBON DIOXIDE (CO_2) EXTINGUISHERS

Carbon dioxide extinguishers are used mainly in putting out electrical fires. They are effective, however, when used on burning fuel oil, gasoline, alcohol, and paint.

The portable extinguisher holds 15 pounds of CO_2 by weight. Carbon dioxide is released by squeezing the release lever. This is the standard Navy type; however, you may still encounter some of the older types operated by handwheel.

When CO_2 is released from the container, it expands rapidly

to 450 times its stored volume. This rapid expansion causes the temperature to drop to 100° below 0° F. Most of the liquid carbon dioxide is vaporized to gas, but some of it forms snow. Don't touch this snow. Its very low temperature will blister the skin and cause painful burns.

CO_2 is most effective in a confined area. If there is wind or a draft, work so that the carbon dioxide will be blown or sucked over the fire, not away from it. Large ships have installed cylinders containing 50 pounds of carbon dioxide. These cylinders are connected to a manifold and used with a hose and reel or a fixed piping sytem. On the newer installations these cylinders are operated with a Navy standard, Type I, Class C valve.

When you are using CO_2, KEEP THE COMPARTMENT CLOSED AND SECURE THE VENTILATION to prevent unnecessary dilution of the CO_2. Except in an emergency, the fire-fighter should not open a compartment flooded with CO_2 for at least 10 minutes after it has been flooded. This delay is a precautionary measure

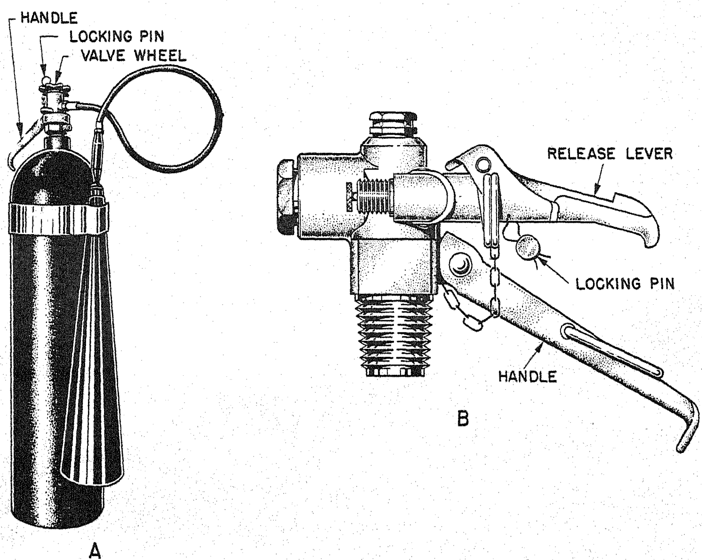


Figure 385.— Portable CO_2 extinguisher with squeeze type release valve.

to give burning substances time to cool down below their ignition temperatures, and thereby prevent their re-ignition upon readmission of air.

CO_2 in high concentrations will produce asphyxiation. It will cause suffocation as rapidly as it will smother a fire unless proper precautions are taken. Don't use it unless you KNOW what you are doing. A compartment flooded with CO_2 may be entered if you use an approved Navy oxygen breathing apparatus or hose (air-line) mask. Otherwise, it should not be entered until a SAFETY LAMP, lowered into the compartment, burns without interruption. DO NOT USE A CANNISTER-TYPE GAS MASK as it merely filters the air without adding the necessary oxygen to it.

THE HANDY BILLY

The handy billy is a lightweight, compact, fire-fighting apparatus complete with rotary-type pump, driven by a two-cycle, two-cylinder, gasoline engine. The pump, engine, fuel tank, and other necessary accessories are mounted on a common base. All are inclosed in a tubular steel frame. The complete unit weighs 106 pounds and can be handled by one man. Each unit is equipped with an S-type foam proportioner and provided with three 10-foot lengths of 2-inch suction hose, a suction strainer, one 10-foot length of 1½-inch exhaust hose, and one mechanical-foam nozzle.

A handy billy with a suction lift of approximately 20 feet is designed to deliver 60 gallons of water per minute at a discharge pressure of 100 pounds per square inch when operating at a speed of 3,500 r.p.m. (revolutions per minute). Increased pressure will cause the speed of the engine to drop, while dec[illegible] out pressure or loss of suction will cause the motor to race. It is [illegible] on advisable to allow the engine to race because inadequate [illegible] and lubrication may cause serious damage. Serio[illegible] weight. the unit would result from improper lubrication. Neve[illegible] er. This this unit below decks without arranging to pipe [illegible] nter above decks or to run it through water to eliminate the toxic gases.

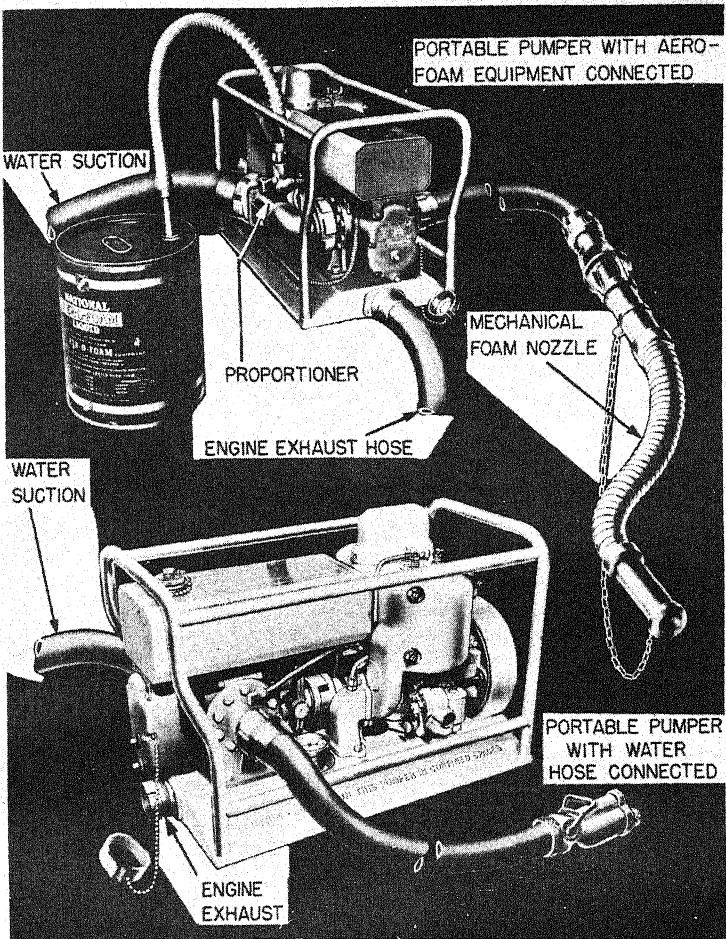


Figure 386.— The handy billy.

P-500 PORTABLE PUMP

[illegible]0 portable centrifugal-type water pump is driven by a compact two-cycle, four-cylinder, water-cooled, gasoline engine of special design. This pump is intended primarily to

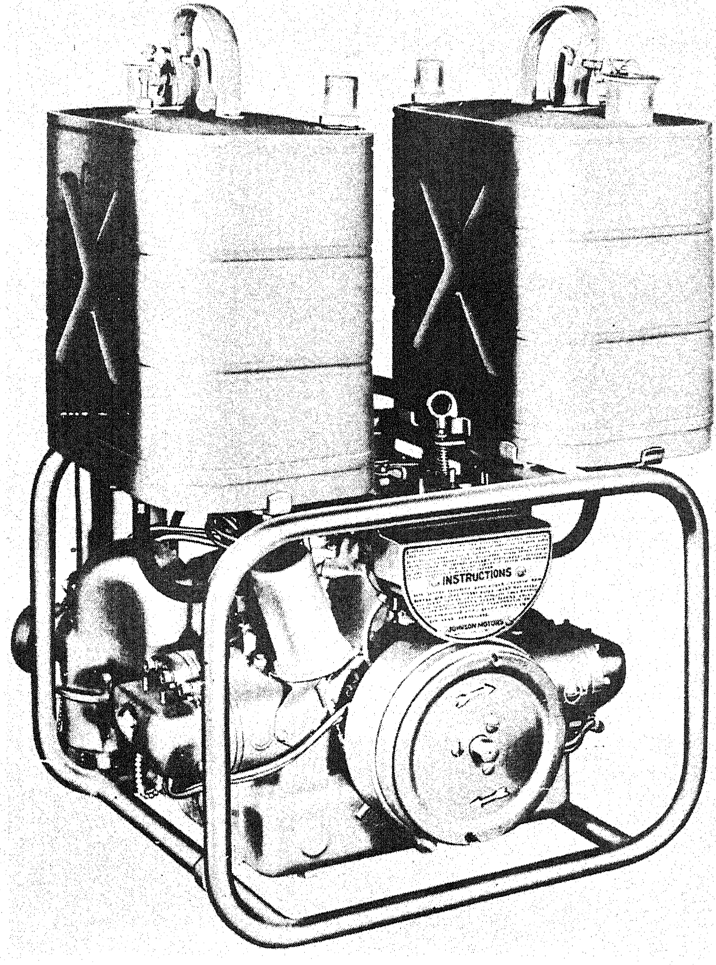


Figure 387.—The P-500 portable pump.

supply water for fighting fires, but can be used for such jobs as removing water from flooded compartments and bilges.

This pump delivers 500 gallons of water per minute at 100 pounds per square inch with a suction lift of 16 feet. With an

eductor the lift may be increased to 50 feet or more, but the water delivery drops proportionately.

With a standard all-purpose nozzle, the P-500 pump can supply six 1½-inch hoses with a pressure of 100 p.s.i.

Suitable means must be provided to carry the poisonous exhaust gases into the clear. A standard 2½-inch rubber suction hose is coupled to the exhaust outlet to remove the gases.

The speed of the engine and the water delivery pressure are controlled by a special pressure regulator, which is usually set for 100 p.s.i. Before the pump is placed in operation it must be primed. Refer to the manufacturer's manual supplied with the pump for instructions on operation and maintenance.

EDUCTORS

Eductors may be used with the P-500 pump for unwatering compartments or for fighting fire thus enabling the pump to lift water more than 16 feet. Figure 388 shows how the eductor is hooked up.

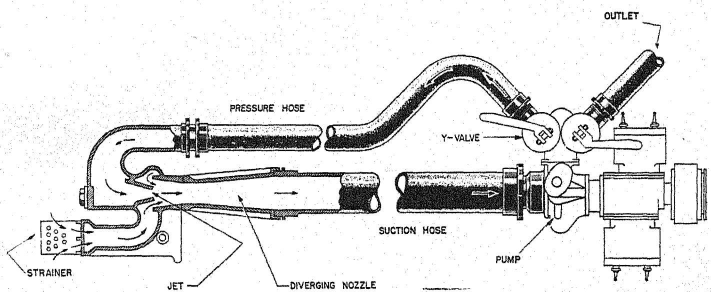


Figure 388.—Eductor connected to suction pump.

The eductor is lowered into the water. The suction hose, pump housing, and pressure hose are primed by the bucket method. The **Y**-valve connected to the eductor is kept open at all times. The engine is started, and when the pressure reaches 75 pounds or more, the other **Y**-valve (connected to the outlet) is slowly opened. Operating on the jet principle, the eductor

assures a constant flow through the suction hose and a constant suction through the strainer.

The eductor may also be connected to a firemain for unwatering a compartment.

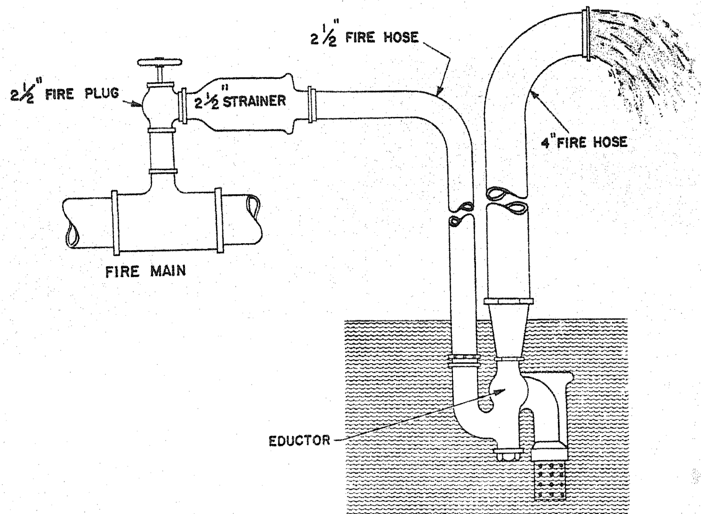


Figure 389.—Eductor actuated by firemain.

STEAM SMOTHERING

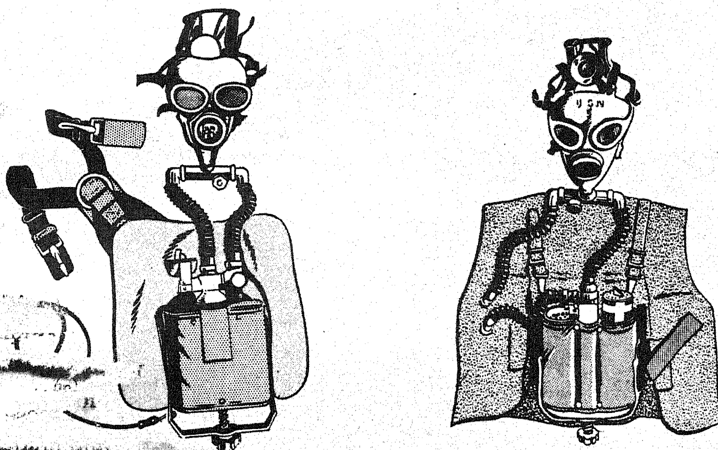
Oil and gasoline fires in confined spaces can be put ou[illegible] steam. The steam smothers the fire in much the same ma[illegible] as does fog. Steam, however, is generally used o[illegible] [illegible]sed to resort—when other such methods as foam or fog are n[illegible] able. The use of steam involves the danger of injury to personnel or damage to equipment. Fires in Class [illegible] may be brought under control with steam but cannot be completely extinguished without the use of water. Learn the location of all control valves for the steam-smothering system on your ship.

SPECIAL PROTECTIVE EQUIPMENT

The Navy believes in protecting its fire fighters. This protection includes the use of —

1. Oxygen-breathing apparatus (three types).
2. Hose (air-line) mask.
3. Asbestos suits.
4. Safety lines (steel-wire).

The two types of Navy breathing apparatus that enable the wearer to work safely in a gas-filled compartment are called type A–1, and patrol type. Each of these devices is self-contained—a "closed circuit" in which oxygen is "generated" for breathing. So long as your breathing apparatus is working, you don't need any outside air.



(g) . ·E A-1

PATROL TYPE

Figure 390.—Navy oxygen-breathing apparatus.

Each breathing unit must have AN OXYGEN SUPPLY, A MEANS FOR COOLING EXHALED AIR, and STORAGE SPACE FOR "RECONDITIONED" AIR (BREATHING BAG).

Each type of apparatus has a special canister which contains chemicals. These chemicals absorb CO_2 and water vapor from the exhaled air, producing a chemical reaction which provides you with a fresh supply of oxygen.

Navy Oxygen Breathing Apparatus, Type A-1

Before donning the apparatus, see that the end of the belt strap is out of the belt buckle, and that the shoulder strap on this buckle side of the apparatus is not snapped on to the body plate; and see that the colors (red, green, and yellow) match on all the tube connections having these colors for identification.

Put your arms through the armholes, snap the unattached shoulder strap onto the body plate, and insert the belt end in the buckle.

Adjust the height of the apparatus on your body by means of the metal slides on the shoulder straps. This height should be such that when the facepiece is put on, the breathing tubes will have enough play in them to permit free movement of the head, and the timer dial will be at the proper distance from the eyes. Adjust the belt strap to a comfortable fit.

Place a canister of chemical in the apparatus. The procedure is as follows: Remove the metal tear-off cap from the top of the canister by pulling the metal tab across the cap and then pulling off the cap. The removal of this cap will reveal the metal-foil seal below. The canister is now ready but the seal for the moment is unbroken. On the apparatus, turn the hand wheel counterclockwise, to the down position. This wheel is used to turn a screw through a supporting bail, or yoke, for the purpose of pushing the canister into place in the canister guard and holding it there. With the screw turned down completely to clear the bottom of the canister guard, pull the bail forward until an unobstructed passage is made for the insertion of the canister. With your free hand, grasp the canister by the bottom and,

keeping the bulged side out, push it as far as it will go into the canister guard. (It will be stopped just short of making contact at the top of the chamber of a "canister stop" on the upper left side of the chamber, which will be released later by hand.) Swing the bail back into place, and lock the canister into the chamber, firmly but not too tightly, by turning the hand wheel clockwise. The apparatus is now ready for patrol, or standby service; you still breathe outside air as the facepiece is not being worn at the time.

To put the breathing apparatus into actual service operation, as in a gas-filled compartment, relieve pressure on the canister by turning the hand wheel counterclockwise, just enough to permit ordinary hand pressure to release the canister stop, and thus clear the way to the top of the chamber. Turn the hand wheel clockwise until a tight contact is made with the canister top against the recess in the plunger housing, where a gasket assures a leakproof seal. (It is at this time that the metal-foil seal is punctured.)

Adjust the straps of the facepiece to an approximate fit. Pull out the headband straps, especially the lower or cheek straps, so that the ends are at the buckles; blow out the dust; insert the chin well into the lower part of the facepiece, and pull the headbands back over the head. To get a firm and comfortable fit against the face at all points, adjust the headband as follows:

(*a*) See that the straps lie flat against the head.
(*b*) Tighten the lower or neck straps.
(*c*) Tighten the side straps, but do not touch the forehead or front straps.
(*d*) Place both hands on the headband pad and push it towards the neck.
(*e*) Repeat operations (*b*) and (*c*).
(*f*) Tighten the forehead or front straps.
(*g*) Test for tightness of the facepiece by pinching both breathing tubes and inhaling.

If the facepiece collapses, it is airtight. If it does not, further adjustment is necessary. (With the facepiece in position, the wearer is cut off from the outside air, and he has only the air in

his lungs. He must draw more air into the apparatus at once through the starter valve.)

Use the following procedure to inflate the breathing bag and properly start the chemical reaction in the canister:

(*a*) Grasp both breathing tubes with one hand, squeeze tightly, depress the starter valve and inhale deeply Release the starter valve and tubes and exhale deeply into the apparatus.

(*b*) Repeat this procedure until the breathing bags are fully inflated (usually three or four breaths).

(*c*) With breathing bags full, exercise (by alternately squatting and standing, or by running or simulating running), until approximately six complete inhalations and exhalations have been taken.

(*d*) Pull the facepiece aside with one hand and deflate the breathing bags with the other hand.

(*e*) Repeat steps (*a*), (*b*), (*c*), and (*d*) until the canister becomes warm on top and bottom, then reinflate with fresh air and proceed with the work to be done.

The chemical in the canister is started by the moisture and the carbon dioxide in the exhaled breath. When a man is working or exercising, the output of moisture and carbon dioxide is greater. In cold weather, part of the moisture in the breath condenses on the interior of the facepiece and breathing tubes reducing the amount which comes in contact with the chemic... This tends to prolong the starting time, which is augmented if canisters are abnormally cold when they are inserted in the apparatus. When the canister and apparatus have been in warm storage (60° F. or above), the starting time is relatively short.

THE CANISTER MUST BE PROPERLY STARTED AND CHECKED TOP AND BOTTOM FOR WARMTH BEFORE ENTERING ATMOSPHERES SUSPECTED OF CONTAINING AN OXYGEN DEFICIENCY, TOXIC GAS, OR SMOKE. Remember that you are entirely dependent on the air within the system; that is to say, in the apparatus and in your lungs. Precautions must always be taken to f... ...ister. ratus in the above manner with enough air to keep a cons... supply of breathable air flowing to the lungs, a process that

cannot proceed without enough air to form a reserve in the breathing bag and to ACTUATE THE CHEMICALS IN THE CANISTER. If, during the use of the apparatus, excess pressure develops in the breathing bag, it may be relieved by momentarily lifting the edge of the facepiece.

Turn the pointer on the timer dial clockwise to number 30. As the apparatus is used, the pointer will return to zero, at which point the warning bell will ring. If there has been no noticeable increase in resistance to breathing, reset the pointer for an additional 15 minutes' work.

When the warning bell rings, indicating a total of 45 minutes, return immediately to fresh air. (The wearer of Type *A* and Type *B* can replace the spent canister with a new one while in toxic air; but the wearer of the patrol type, the Type A-1, or the oxygen cylinder type must return to fresh air.)

To remove a spent canister, spread your legs apart; bend the upper part of the body forward so that the apparatus will fall clear; turn the hand wheel on the bail counterclockwise all the way down; with a quick forward motion, swing the bail outward, allowing the canister to fall to the deck. (Be sure to handle the canister only with suitable protection on the hands, since it will be very hot.) Do not allow any liquid to enter the opening of the canister, and do not hold the face over the canister opening. Oxygen in contact with oil is explosive. The high oxygen content and the high temperature of the chemicals in the canister will cause combustion of inflammable material on contact, especially if the material is moist. Expended or damaged canisters should be punctured in several places and thrown over the stern of the ship as soon after use as practicable. This disposal should not be made, however, if any oil or gasoline is evident upon the surface of the surrounding water, inasmuch as a canister dropped into water so contaminated may explode and the heat of the explosion may be sufficient to ignite the oil or gasoline.

Hose (Air-Line) Mask

If th

Navy has recently authorized the use of a hose mask for fire fighting and damage control work, and this apparatus is

now standard stock. It is very effective and can be constructed easily from the facepiece and breathing tubes of a regular Mark 3 or Mark 4 Navy-type gas mask. The hose mask provides breathing and eye protection in spaces contaminated by any type of gas or vapor, and in a space where there is a lack of oxygen. All that is needed is an air-line hose which will give a continuous supply of pure air to the facepiece at a pressure slightly above the surrounding pressure.

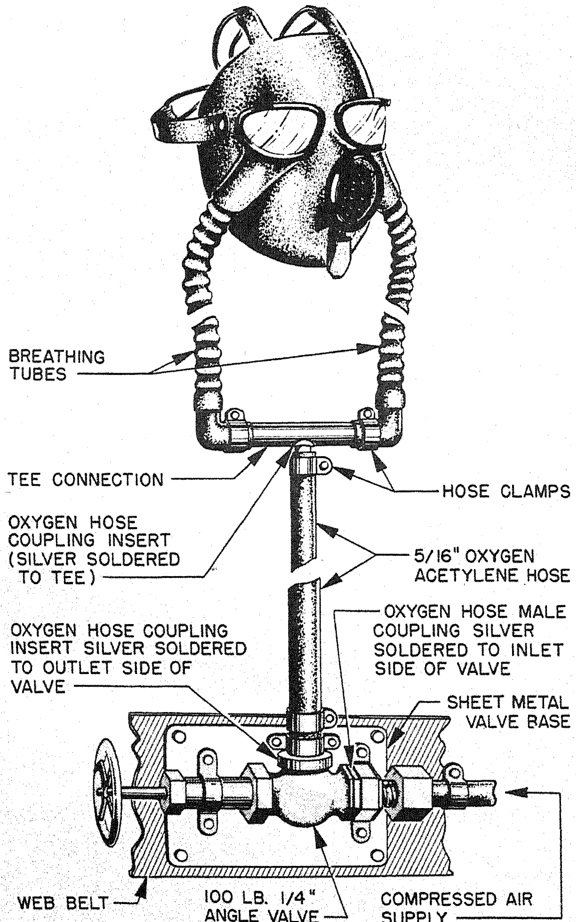


Figure 391.—Assembly of the hose air-line) mask.

The hose (air-line) mask will be found useful on frequent occasions where the conditions make it difficult to use the bulkier oxygen breathing apparatus. It should be part of every well-equipped repair party locker. One length of air hose (and of tender-line) should be attached to the mask at all times, kept neatly coiled and ready for instant connection to any of the available sources of air supply.

The most common source of air supply is the low-pressure ship's service line. Air can also be taken from an air flask. Never use an *oxygen* bottle with this equipment. A small amount of oil, grease, or oily water in the apparatus will combine with the oxygen, causing an explosion.

Before entering a space filled with toxic gases or smoke with this mask, check to see that it is working properly.

The air line and steel safety (life) line of the hose mask, and the steel safety line on any man wearing oxygen-breathing apparatus, must be closely tended at all times by a competent man. He must see that the lines do not become fouled or cut by jagged edges. It is necessary that the wearer and the tender be able to communicate with each other by means of signals, the standard signals being the diver's signals.

If possible, send in at least two men to work as a pair and to maintain visible contact with each other. Men in oxygen breathing apparatus should stand by for any emergency.

Asbestos Suit

Asbestos will not burn, but it does conduct heat. An asbestos suit, therefore, gives protection against flames for only a short tim It does, however, allow the wearer to move quickly through flame to effect a rescue or to do some other job that can be accomplished quickly. The suit may be used with oxygen breathing apparatus worn outside. The wearer should be heavily clothed before putting on the asbestos suit.

When a man is wearing an asbestos suit, it is seldom advisable to spray him with water while he is working on a fire, because the suit would become water-soaked and heavy. If, however,

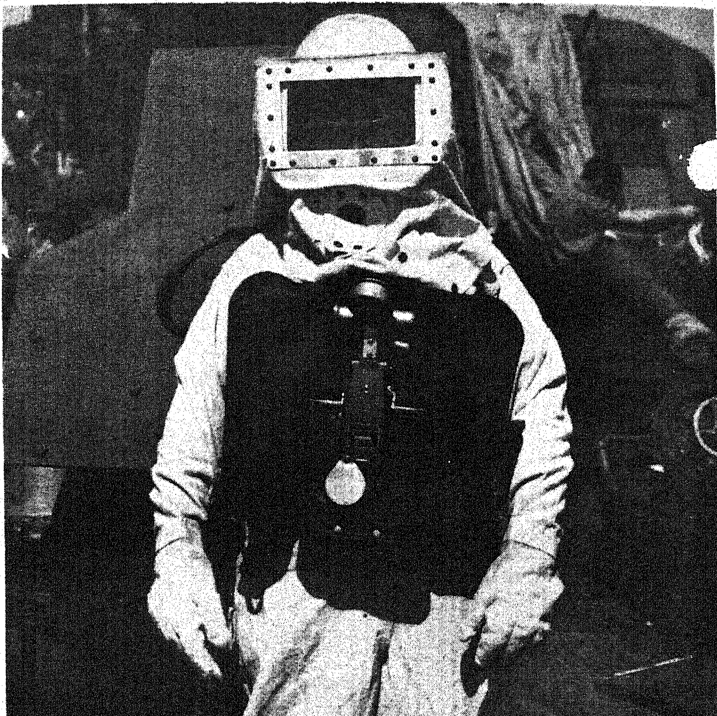


Figure 392.— Firefighter properly clothed.

you are directed to use that procedure, DO NOT STOP THE STREAM OF WATER UNTIL THE MAN IS CLEAR OF THE FIRE AND THE SUIT HAS COOLED. If you stop the water after the suit is wet and still hot, the water will turn to steam and scald the man. The suit must be kept dry or else thoroughly wet at all times. In normal practice, water is not played on the man while he is fighting the fire. In that case, DO NOT SPRAY HIM WHEN HE COMES OUT OF THE FIRE. The hot suit would cause the water to flash into steam, and burn the man.

Life Line

The Navy life line is a 50-foot length of woven steel-wire cable with snap hooks at each end. The life line should be attached to the upper part of the body, preferably to the back of a shoulder harness. Never attach a life line to the waist. If pulled, the line might interfere with the stricken man's breathing or injure him internally.

REMEMBER

Damage control is an around-the-clock job. Day or night, whether at war or at peace, your duty as a member of a damage control party never stops. In fact, the most effective damage control is that which is done before the emergency arises. Remember, it's your job to:

1. KEEP THE SHIP AFLOAT.
2. KEEP THE SHIP UNDER WAY.
3. KEEP THE GUNS FIRING OR READY TO FIRE.
4. PROTECT THE LIVES OF THE CREW.

QUIZ

can be acc... best answer to each of the following statements.
oxygen b...

1. All Watertight doors are secured with—
   - (a) Spring loaded hinges.
   - (b) A handwheel.
   - (c) Bolts.
   - (d) Dogs.

2. A horizontal access door set in the deck but not operating with a quick-acting device is called a—
   (*a*) WT door.
   (*b*) Hatch.
   (*c*) Airport cover.
   (*d*) Escape scuttle.

3. The tightness of access closures is usually dependent upon—
   (*a*) A rubber gasket and knife edge.
   (*b*) Rubberized sealing compound.
   (*c*) A knife edge and a groove.
   (*d*) Nonferrous retaining strips.

4. The most satisfactory repair of an unevenly worn knife edge can be accomplished by building-up with—
   (*a*) Wood shims.
   (*b*) Cardboard shims.
   (*c*) Welding.
   (*d*) Metal shims.

5. Proper opening of a WT door would require starting with the dog which is—
   (*a*) Opposite the hinges.
   (*b*) Nearest the hinges.
   (*c*) At each outside corner and work toward the center.
   (*d*) At the outside center and work around alternately toward hinges.

6. A tight fit of a new lens in an airport cover is insured by the use of a—
   (*a*) Rubber gasket.
   (*b*) Cork covered retaining ring.
   (*c*) Caulking compound.
   (*d*) Putty.

7. If new gasket material for an armored hatch is not available, it is best to—
   (*a*) Reverse the old gasket.
   (*b*) Leave old gasket as it is.
   (*c*) Remove old gasket and substitute white lead.
   (*d*) Remove gasket and cement hatch shut.

8. The simplest and quickest way to determine defects existing along a knife edge and gasket is by—
   (*a*) Visual inspection.
   (*b*) The air test.
   (*c*) The chalk test.
   (*d*) Sounding.

9. Visual inspections of all watertight boundaries of a ship are made at least—
   (*a*) Semi-annually.
   (*b*) Annually.
   (*c*) Each 18 months.
   (*d*) Biennially.

10. The best method of locating a leak during a compartment test is to apply—
   (*a*) A soap suds solution.
   (*b*) Prussian blue.
   (*c*) An open flame.
   (*d*) A test paste.

11. Liquid contents of a compartment are determined by—
   (*a*) Flushing.
   (*b*) An air test.
   (*c*) A mercury gage.
   (*d*) Sounding.

12. Drainage for compartments above the waterline is usually accomplished by—
   (*a*) Eductors.
   (*b*) Gravity.
   (*c*) The main drainage system.
   (*d*) The secondary drainage system.

13. A higher lift may be secured with a submersible type pump if—
   (*a*) A larger suction valve is installed.
   (*b*) An additional electrical current is supplied.
   (*c*) Two or more pumps are placed in tandem.
   (*d*) The discharge port is enlarged.

14. The system designed to supply ample salt water for fire fighting is called a—
   (*a*) Submersible pump system.
   (*b*) Tandem pump system.
   (*c*) Firemain.

15. A ship's ventilation system helps in preventing fires by—
   (*a*) Preventing explosive gas accumulation.
   (*b*) Creating a vacuum in case of explosion.
   (*c*) An incorporated spray system in ventilation blowers.
   (*d*) A thermostatically controlled no-draft system.

16. Air for compartment testing comes from the system known as—

(a) High-pressure.
(b) Low-pressure.
(c) Gas-ejecting.
(d) Atmospheric.

17. Doors, hatches, and valves which must be left open during battle are designated—

(a) X fittings.
(b) W fittings.
(c) X and Y fittings.
(d) X, Y, and Z fittings.

18. Temporary repairs may be made on small holes in the under-w... hull by use of—

(a) Oakum.
(b) A painted hardwood plug.
(c) A soft, unpainted wooden plug.
(d) Shoring.

19. When damaged members are braced so they stand excessive pressure it is called—

(a) Sounding.
(b) Wedging.
(c) Shoring.

20. The oxygen content of the air in a compartment may be checked with a—

(a) Safety lamp.
(b) Explosimeter.
(c) Hydrocarbon vapor indicator.
(d) Oxygen mask.

21. A Class C electrical flame may be best extinguished by—

(a) Steam smothering.
(b) A solid stream of water.
(c) Carbon dioxide (CO_2).
(d) The sprinkling system.

22. In order that folds are made in different places, a fire hose should be refaked—

(a) Daily.
(b) Weekly.
(c) Monthly.
(d) Semi-annually.

23. If the lever on an all-purpose fire nozzle is in the rear position, the nozzle is—
   (*a*) Set for a solid stream of water.
   (*b*) Set for low velocity fog.
   (*c*) Set for high velocity fog.
   (*d*) Shut-off.

24. For thorough mixing, the minimum length of the hose on a continuous type foam generator should be at least—
   (*a*) 25 feet.
   (*b*) 50 feet.
   (*c*) 100 feet.
   (*d*) 200 feet.

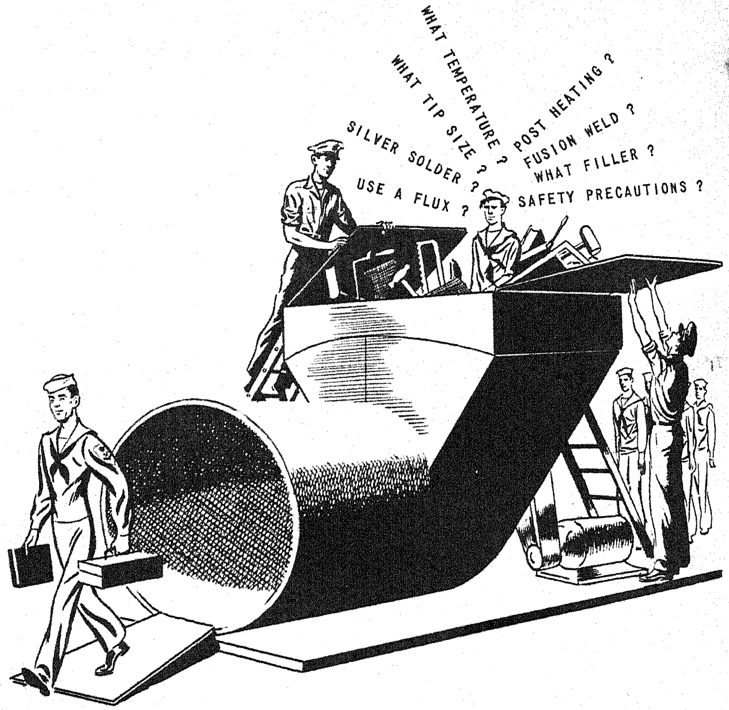
25. The proportioner of a high capacity fog-foam system will act as a water pump if the control valve position is—
   (*a*) "On."
   (*b*) "Off."
   (*c*) "Prime."
   (*d*) "Foam."

26. A fire-fighting device carried on vessels where there is great danger of gasoline fires is the—
   (*a*) Sprinkling system.
   (*b*) Steam smothering system.
   (*c*) Straight-stream water system.
   (*d*) Fixed fog-spray installation.

27. The lift of a P-500 portable pump may be increased to 50 feet or more by using—
   (*a*) A handy billy.
   (*b*) An eductor.
   (*c*) A tandem system.
   (*d*) A booster.

28. The substance removed from exhaled air by the chemical in an oxygen-breathing unit is—
   (*a*) Oxygen.
   (*b*) Carbon.
   (*c*) Carbon monoxide.
   (*d*) Carbon dioxide.

29. The most common air supply for an hose (air line) mask is the—
   (*a*) Oxygen bottle.
   (*b*) High-pressure compressed air system.
   (*c*) Low-pressure ship's service line.
   (*d*) Life line.



CHAPTER 15

IRISH PENNANTS—TUCK 'EM IN!

Irish pennants, odds and ends, ideas adrift—tuck 'em in! You've picked up a lot of knowledge, and you've done a lot of jobs. Now, get squared away and take a bearing on yourself. Just how much have you learned about the many duties and skills required of a Metalsmith? You know your job, and you know just how you and that job fit into your ship's organization. You even have a pretty good idea of just where your ship fits into the Navy and the Military Establishment. You are familiar with the tools and equipment with which your work is done. You've explored some of the secrets of the material with which you work by heat-treating and testing. Annealing,

tempering, hardening, and forging are terms that mean something. You know that everything doesn't have to come from GSK—you can beat out a simple tool on the anvil if the tool isn't available. You never have to worry about what you are going to do with your spare time for there's always something that you can layout and form in the sheet metal shop. And you won't have any difficulties in joining pieces, whether by soldering, riveting, brazing, or welding. You could even work your way out of solitary if someone would slip you a cutting torch and a spark lighter. You've had so much practice in damage control and fire drills that you could take a day in combat as nonchalantly as a day in port. Yes, you've learned a lot, but there is still more to learn before you'll be able to relieve your chief. You'll need a lot of knowledge in order to do a good job if you happen to be *the* Metalsmith aboard some small ship or craft. One of the most important things you must know has to do with supplies and spare parts.

SUPPLIES AND SPARE PARTS

A man-of-war must carry at all times enough supplies and spare parts to insure efficient operation for extended periods of time without an outside source of supply. During times of emergency, such as the last war, ships were required to maintain a supply sufficient to last a period of at least six months. Stowage space aboard ship is limited and it is of the utmost importance to requisition all necessary material in amounts in proportion to the estimated needs.

Requisitioning supplies and spare parts sufficient to last the required period of time is to some degree your responsibility. If your duty station is aboard one of the larger vessels, or on board a shore station, you'll not be greatly concerned with the requisitioning of supplies. Aboard larger ships and on stations, the ordering of supplies will be taken care of by a chief or warrant officer. But, if you are the Metalsmith on a small ship, you'll have to assist your division officer, or the head of your department, in requisitioning the supplies and spare parts you need.

You'll use shop records and past experience as a guide to just how much material you'll need. You wouldn't order 500-feet

of 1½-inch angle bar if past experience showed that you had not used that amount in the past year. Neither would you recommend to your division officer that he order only one sheet of 20-gage galvanized sheet metal when past experience showed that you used many times that amount in an average month's work. The requirements for a destroyer will be vastly different from those of a repair ship or tender.

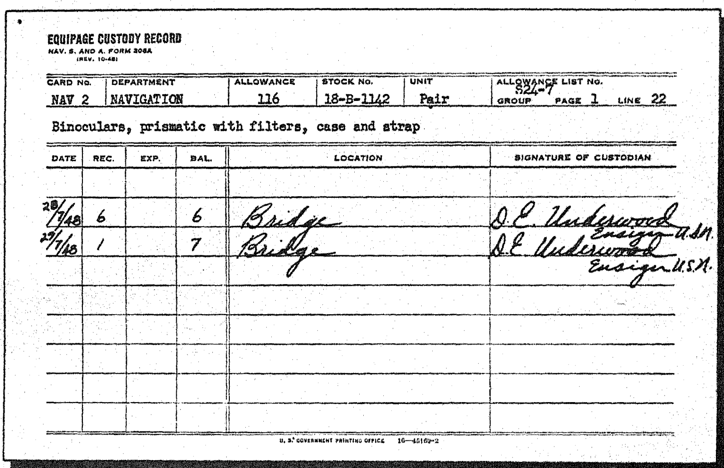
Don't wait until the last minute to start making up your order. It takes a bit of time for the supply officer to replenish your supply. This fact must be taken into consideration or you'll find yourself short of needed material in a time of emergency. You can determine the amount of material you will expend each month by averaging the amount used during the preceding six months. Set a minimum and a maximum amount of material to have on hand. When your stock reaches that minimum point, it is time to reorder to bring the stock pile up to the maximum.

Small items will be stored below in the store rooms by the supply officer; but bulkier items, such as steel plate and angle bar, may have to be stowed topside in racks of your own design. The amount of space you have available for stowage, as well as your estimated needs, will help determine the maximum amount of material that you can carry. You'll have to remember that the average amount of material used in the past is not always the rule to govern your order. Quite often you may have to order specific material in much larger quantities for a particular job. In that case, you'll have to anticipate the need and estimate the material needed prior to the time you intend to start the job. Remember that, depending upon where your ship is located, it'll take the supply office a week to two months to get the material it requisitions for you. So keep sharp and don't get caught short.

Spare parts are usually supplied by the manufacturer of the special tools and equipment in your shop. These spares consist of wearing parts that are likely to need replacements from time to time. For example, your welding machine has a spare-parts box which contains a spare armature, bearings, and various other parts. As these spares are used, you'll have to order

additional replacements from the manufacturers through your supply officer to insure that in the event you are in an isolated region, far from a source of supply, you won't get caught with your welding machine out of service because you forgot to order one spare part.

Accounting for supplies and spare parts is a necessity in the Navy. The armature for your welding machine is a Series 12000 (formerly Title B) item. Your division officer will be required to sign a custody card for it, like the one in figure 393. If you are aboard a small ship, you'll have to sign a similar card which your division officer will keep for his records. Aboard the larger ships and stations, a first class, or chief, will sign the card, but you as the user are responsible for the care of that equipment.



EQUIPAGE CUSTODY RECORD
NAV. S. AND A. FORM 306A
(REV. 10-48)

CARD No.	DEPARTMENT	ALLOWANCE	STOCK No.	UNIT	ALLOWANCE LIST No.
NAV 2	NAVIGATION	116	18-B-1142	Pair	824-7 GROUP PAGE 1 LINE 22

Binoculars, prismatic with filters, case and strap

DATE	REC.	EXP.	BAL.	LOCATION	SIGNATURE OF CUSTODIAN
28/7/48	6		6	Bridge	D. E. Underwood Ensign U.S.N.
29/7/48	1		7	Bridge	D. E. Underwood Ensign U.S.N.

U. S. GOVERNMENT PRINTING OFFICE 16—45160-2

Figure 393.—Custody card.

The replacement of Series 12000 equipage isn't handled in the same way that you'll handle the replacement of expendable items such as rivets. Spare parts for your welding machine and other special tools and equipment are Series 12000 gear. To replace these parts, you'll have to survey the part on a form like the one shown in figure 394. You may be required to fill

out this form in the rough, or to furnish the information so that your division officer can make the survey and replace the part. An accurate account of all Series 12000 equipage is kept, and a periodic inventory is held.

NAV. S. AND A. FORM 154
Revised June 1944

SURVEY REQUEST, REPORT, AND EXPENDITURE

SHIP OR ACTIVITY	DATE	NO.

REQUEST (To be prepared by supply officer, or head of Department)

It is requested that the items listed below be surveyed in accordance with Arts. 1906–1918, N. R.

REASON	APPROPRIATION	SIGNED
ACCOUNT	TITLE	RANK

ITEM	QUANTITY	ARTICLE	IDENTIFYING MARKS, ETC.	DATE AND FROM WHOM RECEIVED	VALUES AT WHICH CARRIED

REPORT (To be prepared by head of Department, or by surveying officer(s) if so directed below)

ITEM	CONDITION, CAUSE, RESPONSIBILITY, AND RECOMMENDATION	APPRAISED VALUE

The above items have been carefully surveyed in accordance with Sec. 3, Chap. 49, N. R., and report is made thereon as indicated above.

DATE

(Signed by surveying officer or board, or by head of Department)

ACTION OF COMMANDANT OR COMMANDING OFFICER

Expend without formal survey, in accordance with Arts. 1909, 1914, N. R.	DATE	COMMANDANT OR COMMANDING OFFICER

or Formal survey is required and

U.S.N. U.S.N.

U.S.N. (is) (are) hereby designated as surveying officer(s) for the above articles or material, in accordance with Art. 1910, N. R.

(Date) (Commandant or Commanding officer)

ACTION BY REVIEWING OFFICER AFTER FORMAL SURVEY

ITEMS APPROVED	ITEMS DISAPPROVED	DATE	SIGNED

NAME OF BUREAU TO WHICH FORWARDED FOR ACTION	DATE

The above articles have been expended from the records at

$

FINAL EXPENDITURE

CHARGE TO TITLE	ACCOUNT	APPROPRIATION

TRANSFERRED TO

SPACE FOR BUREAU APPROVAL IF NECESSARY

EXPENDED / RECEIVED ________, 19____ the above-mentioned articles________ U.S.N.

Figure 394.—Survey request, report and expenditure.

You're probably wondering just where you can find out about

the nonexpendable equipment that you are supposed to have. Your answer to that question is the ALLOWANCE LIST. Long before the ship upon which you are serving was built, plans were drawn, blueprints were made, and an allowance list was made up. The mission or purpose which the ship was to accomplish determined just what those plans, blueprints, and allowance lists included. When your ship was commissioned, everything listed in the allowance list was aboard. That list includes all

NBS 487-S
BuShips Allowance List

BOOK FOR U. S. S. AR 13-14 PART I - MACHINERY

GROUP NAME SHEET METAL SHOP PAGE 12

GROUP No. S91-1-SHM

(A) Line No.	(B) Title	(C) Class or Stock No.	(D) Name and Description of Item	(E) Drawing Numbers: Bureau AR 13-	(F) Drawing Numbers: Contractor AR 13-	(G) Piece No.	(H) Unit of Quantity	(J) Allowance	(M) Furnished by
ø2									
ø2				S9101-					
ø2	B	41	MACHINE, Punching, Stationary	649784	91910-9	8	No.	1	2 BC
			Contract No.: NXss-70849(P)						
5			Maker: Heidemann Machine Co.						
			Philadelphia, Pa.						
			Type: Hand Operated						
			Model: R-2						
			Size: 12" Throat						
10			Serial Nos.:						
ø			AR 13 - 1962						
ø			AR 14 - 1963						
øø2			~~AR 15 - 1964~~						
øø2			~~AR 16 - 1965~~						
15									
			ACCESSORIES - MACHINE						
	B	40	Die & Punch, 1/8"				Set	1	Z BC
	B	40	Die & Punch, 3/16"				Set	1	Z BC
20	B	40	Die & Punch, 1/4"				Set	1	Z BC
	B	40	Die & Punch, 5/16"				Set	1	Z BC
	B	40	Die & Punch, 3/8"				Set	1	Z BC
	B	40	Die & Punch, 7/16"				Set	1	Z BC
	B	40	Die & Punch, 1/2"				Set	1	Z BC
25	B	40	Die & Punch, 5/8"				Set	1	Z BC
	B	40	Die & Punch, 3/4"				Set	1	Z BC
	B	40	Die & Punch, 7/8"				Set	1	Z BC
	B	40	Die & Punch, 1"				Set	1	Z BC
	B	40	Die & Punch, 1-1/4"				Set	1	Z BC
30									
			TOOLS - MACHINE						
	C	41	Handle				No.	1	Z
	C	41	Pusher				No.	1	Z
35	C	41	Shaft, Steel, 3/4" x 3"				No.	1	Z
	C	41	Wrench, Allen, 1/4"				No.	1	Z
	C	41	Wrench, Allen, 3/16"				No.	1	Z
	C	41	Wrench, Bristo, 3/16"				No.	1	Z
	C	41	Wrench, Bristo, 1/8"				No.	1	Z
40									
45									
50									

ø2 Revised 5/3/46
ø Revised 5/19/45
5/7/45

Figure 395.— Sample page from allowance list for fleet repair ship.

equipage and spare parts. From the allowance list for your ship, you can determine, then, just what you are supposed to have on hand and to what series it belongs; that is, whether it is equipment that is expendable or nonexpendable. Figure 395 is a sample page of an allowance list for a fleet repair ship.

Stowage of supplies and spare parts is the next problem you'll have after the material and spares you've ordered arrive on board. The supply officer will receive these materials and stow them in the hold of the ship, or he may turn them over to your division officer. If they are turned over to your division officer that's where you come in. You'll be hunting space for stowage in your shop or stowage bins.

The supply officer maintains an account of all materials and supplies on board. When you need Series 13000 (formerly Title C) or expendable material such as rivets, you'll have to make out a chit to draw the material from the store room. Figure 396 is a BuSandA 307 stub requisition properly filled out, numbered, and signed.

S. & A. Form No. 307
Revised July 1944

Stub Requisition No. ....

U. S. S. ARDMORE (AD-18)

10 January, 1948

To Supply Officer: Request following stores be delivered to bearer for use in the Engineering Department.

W. T. Door Chr U.S.N.
By authority of Head of Department.

Standard Stock Catalog No. or Class No.	Description of Article	Quantity Required	Unit of Quantity	Unit Price	Extension
	Drill, breast, chuck 0 to 1/2	1	Ea		
	Hammers, claw, 1 lb	2	Ea		

Total ....

Received the above material.

Issued by: H. Swim

.... M 3, U.S.N.
Storeroom Keeper.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1944 16—40667-1

Charged on ledger ....
Allotment charged ....

Figure 396.—Stub requisition.

When you've made out your chit, had it signed by your division officer or department head, and numbered by the

supply office, you'll then present it to the storeroom keeper who will issue the material to you. The responsibility for stowage in the shop is yours. Space available and ingenuity on your part will determine how shipshape your shop will be. Just as you wouldn't order large quantities of material which you seldom use, neither should you have an overabundance of the same sized rivets or welding rods taking up much needed space in the shop. Figure 397 is an improvised means for stowing these supplies.

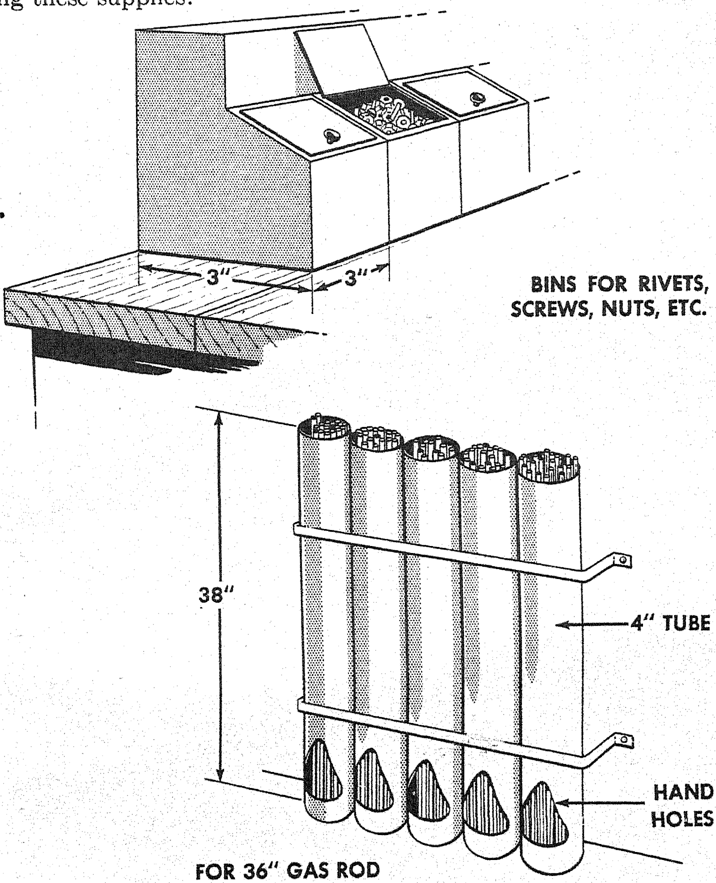


Figure 397.—Stowage of rivets and welding rod.

You can set up racks like those shown in figure 398 for overhead and on the deck stowage of sheet metal and plate.

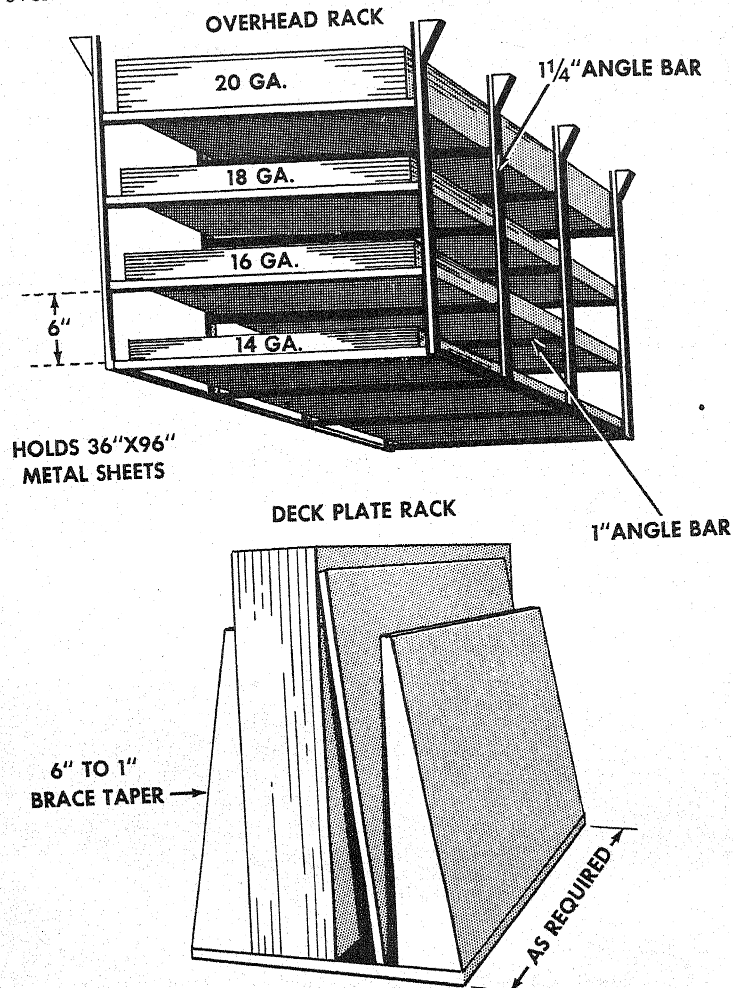


Figure 398.—Stowage of sheet and plate.

A point on stowage that can't be overstressed is the stowage of acetylene and oxygen cylinders. Be sure that your acetylene

bottles are stowed on end with the valve end up. Never allow them to lie on their side or the acetone will enter the valve and work into the regulator and hose, and finally into the weld, spoiling your joint. Oxygen bottles should be kept out of the direct rays of the sun in a cool dry place, away from any source of grease, oil, or other combustible material. All bottles containing gases should be stowed in suitable racks and secured at all times. Figure 399 is an example of a good way to secure your cylinders.

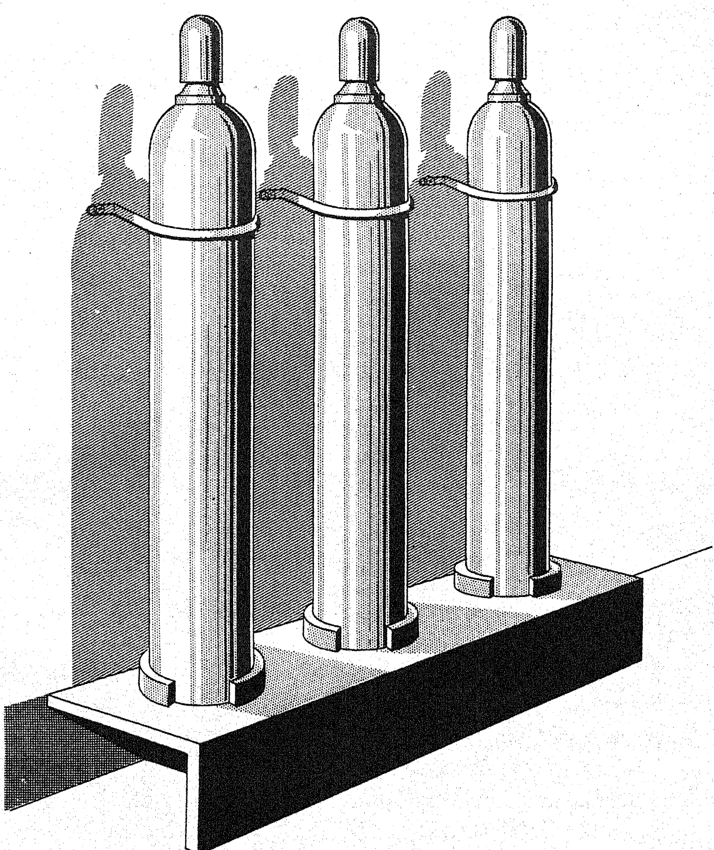


Figure 399.— Gas bottle rack.

You won't spend many days around a metal shop before you'll come in contact with a job order. Aboard repair ships and tenders, you'll see this job order on paper. If you are on a destroyer, your job order will likely be a verbal order from your division officer or department head. Whether it's verbal or written up on a job order form, it amounts to the same thing. A sample job order is shown in figure 400.

NRB—43585—10 Aug 44—500.

U. S. S. BENNINGTON
SHIP'S FORCE JOB ORDER
(Submit in Duplicate)

From: ....

To : Chief Engineer.

Request Following Ship's Force Repairs

....

Signed: ....

....
U. S. Navy

From: Chief Engineer.

To : ....

Approved
Disapproved

....
Commander, USN
Chief Engineer

To: ....

Comply as Directed.

Priority "A" "B" "C"

Material Required:

....

Started: ....

Accomplished by: ....

Completed and Inspected: ....

Entered in Machinery History.

By: ....

Figure 400.—Job order.

A job order contains certain specific information. The most important information given, so far as you are concerned, is the description of the work that you are to do.

Priorities are assigned a job order to designate the importance or urgency of the work requested. The designation will vary with the activity concerned. You'll have to acquaint yourself with the system employed by your ship or station. The follow-

ing is typical of the priority system: The letter *A* designates work of an emergency nature, *B* designates important jobs that must be started as soon as possible, and *C* is assigned to work that is desirable but routine. Priority *A* is reserved for emergency jobs. They take precedence over all other work. *B* jobs must give way to priority *A* jobs. They are to be done during the regular working day. The activity making the request for work requests the priority desired for the work, but the final assignment or designation is made by the repair officer.

As the Metalsmith on board a small ship, you'll very likely be called upon to assist in making up work requests for repairs and alterations to be done by a tender, repair ship, or a naval ship yard. The important point to remember is this: state the exact nature of the work to be accomplished. Work requests will vary in different activities. The one that you use on your ship may not be exactly like the one shown in the illustration, but the information shown will be very much the same. The work requests that you submit to a repair activity, either shore-based or afloat, must be a bigger job than the ship's crew is trained or equipped to do for itself. Figure 401 shows a repair request. For further information regarding repairs, alterations, and work requests read Chapter 12, *U. S. Navy Regulations*.

Records are kept and reports are made by the first class or chief aboard larger vessels. If you happen to be on one of the smaller ships, this duty may very easily be yours. Such records aid you in estimating the amount of material which you have used and will need when requisitioning replacements. They are also valuable as a record of the work performed, the amount of material expended on each job, and the number of man hours required to accomplish a given job. Figure 402 illustrates one of the several ways in which this record can be kept.

From the record or shop log, you can estimate the amount of material you'll need for future use by compiling the amount of material you have used in an average month, and multiplying that amount by the number of months for which you have to order. Bear in mind, though, the amount of stowage space that you have available. In addition to having an aid for the purpose of estimation, you'll also have a complete record of

N.S.O. 105

U. S. S. .... Date .... Serial No. ....

REPAIR REQUEST

Urgent
Desirable .... Bureau having cognizance ....
(Cross out one)
Group name or designation of machinery unit, appliance, or part of ship:

....
(Group name) (Group number)

To:

1. The following condition requires navy-yard work:

2. Due to the above conditions, the following repairs are recommended:

3. Ships force will assist as follows:

4. Repair facilities of forces afloat have been investigated and they are unable to undertake this item for the following reasons:

(Signed) ....
U.S.N., Commanding

NOTE.—In preparation of repair requests, read U.S.N. Regulations, Ch. 51, arts. 1970, 1971, and 1973, General Order No. 55, and Fleet and Force Regulations.

Figure 401.—Repair request.

the work you have performed if you keep your shop log up-to-date. Your log should include the date the job was started, completed, and the amount of time and material consumed in doing the job. There can't be any argument when your shop log is kept up to date. You have it down in black and white.

SHOP WORK & J. O. LOG

J.O.#	Date Received	Originator	Prior ity	Job Description	Date Completed	Man Hours	Material Expended
1-48	2-5-48	Supply	B	Mfg. + Install Book Shelf in Disbursing Off.	2-7-48	4	3'-¾" angle bar 1 sheet 16g. Galv.
2-48	2-6-48	C + R	B	Repair by Welding 5 Disk Rack	2-7-48	3	

Figure 402. — Sample shop work and job order log.

Hold a monthly inventory. Keep a close check on your stock pile. Don't wait until you are out of an item before you decide to reorder.

Making *man-hour reports* probably won't be one of your duties until you make first class or chief, but if you are assigned to a repair ship, you'll no doubt be seeing these reports around. The man-hour report accounts for the total amount of working hours available to the shop. This report may seem unnecessary to you, but for the Engineer Officer it's necessary information. It will enable him to know how much time his men are spending on working parties, in sick bay, on on-the-job training, and on special liberty. As the petty officer in charge of the shop, you will know exactly what your men are doing at all times. But the head of the department, who may have as many as 250 men working under him, can't keep himself informed as to the number of man hours available to him unless these reports are made and records kept. On the basis of these

reports and other records, he is able to back up his statements when discussing the availability of men for working parties for the supply department or other departments of the ship. These reports vary with the individual ship and department head. Records, reports, and paper work may seem unnecessary at times, but it's well to remember that a well-organized efficient department can't operate without some paper work.

One of the pieces of paper work that can be avoided is an accident report. You know by now that if you or one of your shipmates is injured in your shop, an investigation is required. This investigation attempts to determine the cause of the accident in order that future accidents of the same or similar nature may be eliminated. If you are the individual involved, or if you are present when the accident occurs, you'll probably be asked to make a statement. It's a lot easier and you'll be a lot happier if you do all in your power to prevent such occurrences and the resulting paper work.

PLAY IT SAFE

Be careful—the life you save may be your own! Even if it's only a finger or an eye that you save, it is well worth your time and trouble. Injuries run pretty high among metal workers, although most of them could be avoided. From both the frequency and severity standpoint, finger accidents rank the highest. Eye injuries rank next to finger injuries, and arm, hand, and head wounds occur less frequently.

Grinders and buffers will usually account for the greatest number of injuries, with drills running a close second. Rollers and benders come in for a lion's share of the accidents also. Of course, some of the most serious accidents happen infrequently, but you'll be just as dead if you are killed by a freak accident. Hot soldering irons, live wires, molten slag, and hot metal are all danger signals, even if they aren't hot enough to be red. It would be impossible to list in one chapter all of the safety precautions that you need to remember and observe. And it would be just as impracticable for you to memorize them if you didn't use some good common sense and put them into

practice in your daily routine. There are a few good generalizations that you can remember, and that you'll need to be reminding your men about when you are leading petty officer, or in charge of your own metal shop.

1. Keep your mind on your job.
2. Keep your working spaces shipshape, even if you aren't expecting an inspection.
3. Secure all tools in their proper places.
4. Never go away and leave an electric tool or machine running or with the juice on, even for a few minutes.
5. Don't attempt to adjust, oil, or clean a machine while it is in motion.
6. Wear the proper protective clothing for the job you are doing, even if it is but a small job.
7. Wear close fitting clothing. Avoid loose sleeves, and other loose ends. Rings are also dangerous.
8. Make sure that all guards are in place on the machine you are about to use.
9. Don't switch parts on machines and don't experiment with over-capacity jobs.
10. Use a brush or hook to remove shavings. Don't use your hands.
11. Don't allow oxygen to come in contact with oil and grease.
12. Keep sparks, flames, and heat away from acetylene.
13. Don't use faulty equipment or makeshift tools.
14. Don't make a cut with a cutting torch until you know what is on the other side of the metal you are about to cut. Keep a man with a fire extinguisher close by.
15. When you are brazing, or silver soldering, be sure you are getting plenty of fresh air. Zinc fumes are poisonous.
16. Locate the fire extinguishers in your shop. It's too late to learn their whereabouts after the fire has started.

Make a point of knowing just a little more than is required of [illegible] And be consistent about putting that knowledge into practice. Take no chances; PLAY IT SAFE.

reports and other records, he is able to back up his statements when discussing the availability of men for working parties for the supply department or other departments of the ship. These reports vary with the individual ship and department head. Records, reports, and paper work may seem unnecessary at times, but it's well to remember that a well-organized efficient department can't operate without some paper work.

One of the pieces of paper work that can be avoided i- -n accident report. You know by now that if you or one c shipmates is injured in your shop, an investigation is requ This investigation attempts to determine the cause of the accident in order that future accidents of the same or similar nature may be eliminated. If you are the individual involved, or if you are present when the accident occurs, you'll probably be asked to make a statement. It's a lot easier and you'll be a lot happier if you do all in your power to prevent such occurrences and the resulting paper work.

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Make a point of knowing just a little more than is required of you. And be consistent about putting that knowledge into practice. Take no chances; PLAY IT SAFE.

QUIZ

Select the one best answer to each of the following statements.

1. The responsibility for the care of equipment signed for on an equipage custody record is that of the—
   (a) Person signing the record.
   (b) User of the equipment.
   (c) Division officer.
   (d) Supply officer.

2. The replacement of non-expendable equipment, such as a special tool, requires—
   (a) Repair request.
   (b) Job order.
   (c) Periodic inventory.
   (d) Request for survey.

3. The record to check to find out the required equipment which a Metalsmith should have, is the—
   (a) Allowance list.
   (b) Equipment custody record.
   (c) Job order log.
   (d) Chit.

4. To draw expendable materials, the Metalsmith will make out—
   (a) An equipment custody record.
   (b) A request for survey.
   A chit.
   (d) A job order.

5. The responsibility of stowage in the metal shop is that of the—
   (a) Supply Officer.
   (b) Division Officer.
   (c) Storekeeper.
   (d) Metalsmith.

6. If defects appear in a weld as a result of excess acetone, it may indicate that the—
   (a) Acetylene cylinder has been stowed improperly.
   Gas has been poorly mixed.
   (c) [illegible] tip is too large.
   Hot sore
   (d) Gas [illegible] is 1 to 1.

7. If the improper stowage brings oxygen [illegible] aren't hot enough [illegible] char [illegible] would be—
   (a) An improper mixing ratio when used for continuous welding.
   (b) An oxidizing torch flame.
   (c) An explosion.
   (d) An unsuitable gas for welding.

8. If a job order calls for priority "A", the work is—
   (*a*) To be started as soon as possible.
   (*b*) Of an emergency nature, requiring immediate action.
   (*c*) Routine.
   (*d*) To be accomplished after priority "B".

9. A Metalsmith's future material estimates will probably be determined—
   (*a*) On a previous average monthly consumption.
   (*b*) By the size of stowage space.
   (*c*) On previous monthly averages plus 25%.

APPENDIX I

ANSWER TO QUIZZES

CHAPTER 1

THE METALSMITH'S WORK

1. (*d*)
2. (*a*)
3. (*b*)

CHAPTER 2

TOOLS AND EQUIPMENT

1. (*c*)	16. (*b*)
2. (*a*)	17. (*d*)
3. (*c*)	18. (*a*)
4. (*d*)	19. (*c*)
5. (*d*)	20. (*d*)
6. (*c*)	21. (*a*)
7. (*d*)	22. (*b*)
8. (*b*)	23. (*a*)
9. (*d*)	[illegible]
[illegible]	[illegible]
[illegible] (*c*)	[illegible] (*c*)
12. (*b*)	27. (*c*)
13. (*b*)	28. (*a*)
14. (*a*)	29. (*c*)
15. (*d*)	

CHAPTER 3

MATERIALS

1. (*b*)	17. (*a*)	33. (*n*)
2. (*d*)	18. (*c*)	34. (*a*)
3. (*a*)	19. (*d*)	35. (*f*)
4. (*c*)	20. (*b*)	36. (*m*)
5. (*a*)	21. (*a*)	37. (*l*)
6. (*c*)	22. (*c*)	38. (*g*)
7. (*d*)	23. (*b*)	39. (*h*)
8. (*b*)	24. (*d*)	40. (*j*)
9. (*a*)	25. (*c*)	41. (*d*)
10. (*c*)	26. (*a*)	42. (*e*)
11. (*b*)	27. (*b*)	43. (*i*)
12. (*d*)	28. (*d*)	
13. (*c*)	29. (*c*)	
14. (*d*)	30. (*a*)	
15. (*b*)	31. (*b*)	
16. (*b*)	32. (*d*)	

CHAPTER 4

HEAT-TREATMENT OF METALS

1. (*d*)	16. (*b*)
2. (*c*)	17. (*c*)
3. (*b*)	18. (*a*)
4. (*a*)	19. (*c*)
5. (*a*)	20. (*a*)
6. (*c*)	21. (*d*)
7. (*a*)	22. (*b*)
8. (*b*)	23. (*a*)
9. (*d*)	24. (*c*)
10. (*d*)	25. (*d*)
11. (*b*)	26. (*b*)
12. (*a*)	27. (*a*)
13. (*d*)	28. (*d*)
14. (*b*)	29. (*c*)
15. (*a*)	30. (*b*)

CHAPTER 5

METAL TESTS

1. Color, appearance, chip, spark, torch.
2. Spark stream, color, sparks.
3. Carbon.
4. Four (4).
5. Rate, appearance.
6. Dull red.
7. Medium.
8. Sparking.
9. Light, high, heavy, low.
10. Speed, pressure.
11. Soft.
12. Inaccuracy.
13. 32,000.
14. Neck, elongate.
15. Tensile.
16. 180.
17. Fatigue.
18. (*d*)
19. (*c*)
20. (*a*)
21. (*c*)
22. (*b*)

CHAPTER 6

SOLDERING WITH SOFT SOLDERS

1. (*b*)
2. (*b*)
3. (*d*)
4. (*c*)
5. (*d*)
6. (*b*)
7. (*d*)
8. (*a*)
9. (*d*)
10. (*b*)
11. (*d*)
12. (*a*)
13. (*b*)
14. (*b*)
15. (*c*)
16. (*d*)
17. (*c*)
18. (*c*)
19. (*b*)
20. (*d*)
21. (*a*)
22. (*c*)
23. (*b*)
24. (*d*)
25. (*a*)
26. Melting point.
27. Forward-backward.
28. Finished.
29. Bead.
30. Rust-corrosion.
31. (*d*)
32. (*b*)
33. (*b*)
34. (*f*)
35. (*a-c*)
36. (*b-e*)
37. (*a-c*)
38. (*b*)
39. (*f*)

CHAPTER 7

BRAZING AND RELATED JOINING METHODS

1. (*c*)
2. (*c*)
3. (*c*)
4. (*b*)
5. (*c*)
6. (*d*)
7. (*a*)
8. (*c*)
9. (*d*)
10. (*b*)
11. (*d*)
12. (*b*)
13. (*d*)
14. (*a*)
15. (*a*)
16. (*c*)
17. (*b*)
18. (*a*)
19. (*d*)
20. (*a*)
21. (*d*)
22. (*a*)
23. (*a*)
24. (*c*)
25. (*b*)
26. (*d*)
27. (*a*)
28. (*d*)
29. (*c*)
30. (*b*)
31. (*a*)
32. (*b*)
33. (*d*)
34. (*c*)

CHAPTER 8

OXYACETYLENE WELDING

1. (*c*)	18. (*a*)
2. (*a*)	19. (*e*)
3. (*a*)	20. (*b*)
4. (*a*)	21. (*g*)
5. (*b*)	22. (*d*)
6. (*b*)	23. (*a*)
7. (*c*)	24. Step 1 (*j*)
8. (*d*)	25. Step 2 (*g*)
9. (*a*)	26. Step 3 (*a*)
10. (*c*)	27. Step 4 (*b*)
11. (*b*)	28. Step 5 (*i*)
12. (*d*)	29. Step 6 (*c*)
13. (*b*)	30. Step 7 (*h*)
14. (*c*)	31. Step 8 (*d*)
15. (*f*)	32. Step 9 (*f*)
16. (*b*)	33. Step 10 (*e*)
17. (*d*)	

CHAPTER 9

ARC WELDING

1. (*d*)	12. (*e*)
2. (*a*)	13. (*i*)
3. (*c*)	14. (*d*)
4. (*b*)	15 (*l*)
5. (*d*)	16. (*b*)
6. (*b*)	17. (*g*)
7. (*a*)	18. (*c*)
8. (*c*)	19. (*m*)
9. (*a*)	20. (*f*)
10. (*d*)	21. (*k*)
11. (*b*)	22. (*a*)

CHAPTER 10

OXYACETYLENE CUTTING OF METALS

1. (*d*)
2. (*b*)
3. (*c*)
4. (*c*)
5. (*a*)
6. (*d*)
7. (*b*)
8. (*d*)
9. (*b*)
10. (*c*)
11. (*b*)
12. (*d*)
13. (*a*)
14. (*c*)
15. (*a*)
16. (*d*)
17. (*b*)
18. (*c*)
19. (*b*)
20. (*d*)
21. (*c*)
22. (*a*)
23. (*d*)
24. (*b*)
25. (*c*)

CHAPTER 11

SHEET METAL MEASUREMENT AND LAYOUT

1. (*b*)
2. (*a-c*)
3. (*e*)
4. (*a*)
5. (*f*)
6. (*g*)
7. (*d*)
8. (*b*)
9. (*c*)
10. (*d*)
11. (*d*)
12. (*b*)
13. (*c*)
14. (*c*)
15. (*c*)
16. (*a*)
17. (*d*)
18. (*c*)
19. (*c*)
20. (*b*)
21. (*a*)
22. (*d*)
23. (*c*)
24. (*a*)
25. (*b*)
26. (*d*)
27. (*c*)
28. (*a*)

CHAPTER 12

HAND AND MACHINE PROCESSES IN SHEET METAL WORK

1. (*d*)
2. (*b*)
3. (*c*)
4. (*a*)
5. (*b*)
6. (*d*)
7. (*a*)
8. (*c*)
9. (*c*)
10. (*a*)
11. (*d*)
12. (*b*)
13. (*a*)
14. (*d*)
15. (*b*)
16. (*c*)
17. (*d*)
18. (*a*)
19. (*c*)
20. (*b*)
21. (*d*)
22. (*c*)
23. (*a*)
24. (*c*)
25. (*b*)
26. (*a*)
27. (*c*)
28. (*a*)
29. (*c*)
30. (*b*)
31. (*d*)
32. (*b*)

CHAPTER 13

BLACKSMITH WORK AND FORGING

1. (*d*)
2. (*b*)
3. (*c*)
4. (*a*)
5. (*b*)
6. (*d*)
7. (*c*)
8. (*a*)
9. (*c*)
10. (*b*)
11. (*d*)
12. (*c*)
13. (*d*)
14. (*b*)
15. (*d*)
16. (*b*)
17. (*a*)
18. (*c*)
19. (*a*)
20. (*c*)
21. (*d*)
22. (*b*)
23. (*d*)
24. (*c*)
25. (*a*)
26. (*c*)

CHAPTER 14

EMERGENCY DUTIES

1. (*d*)
2. (*b*)
3. (*a*)
4. (*c*)
5. (*b*)
6. (*d*)
7. (*a*)
8. (*c*)
9. (*a*)
10. (*a*)
11. (*d*)
12. (*b*)
13. (*c*)
14. (*c*)
15. (*a*)
16. (*b*)
17. (*b*)
18. (*c*)
19. (*c*)
20. (*a*)
21. (*c*)
22. (*c*)
23. (*a*)
24. (*c*)
25. (*b*)
26. (*d*)
27. (*b*)
28. (*d*)
29. (*c*)

CHAPTER 15

IRISH PENNANTS — TUCK 'EM IN!

1. (*b*)
2. (*d*)
3. (*a*)
4. (*c*)
5. (*d*)
6. (*a*)
7. (*c*)
8. (*b*)
9. (*a*)

APPENDIX II

METALSMITHS (ME)

General Service Rating

Metalsmiths lay out, fabricate, and repair metal structures (light and heavy gage). Make repairs involving welding, brazing, riveting, and calking to decks, structures, and hulls. Layout, cut, shape, rivet, and tin plate sheet metal. Do various types of hot and cold forming and heat treatment of metals. Act as members of damage control parties; calk or patch leaks in the hull, tanks, or bulkheads; check watertight integrity.

Emergency Service Ratings

Title	Abbr.	Rating Code No.	Definition
Metalsmiths G	MEG	521	Make repairs involving welding, brazing, drilling, riveting, and calking to decks, hulls, bulkheads, and tanks. Make lift templates. Use shop, hand, and power-driven tools. Check watertight integrity by making air tests of doors, hatches, ports, manholes, and tanks.
Metalsmiths S	MES	522	Fabricate and repair sheet metal and light plate structures; lay out, shear, rivet, weld, braze, tin, and solder sheet metal. Use hand, power-driven, and shop tools. Are assigned to CB and Ship Repair activities.
Metalsmiths B	MEB	523	Forge, heat-treat, case-harden, and forge-weld metals; fabricate hand tools, metal shapes, structural members, hooks, shackles, brackets, etc. Operate furnaces and forges. Are assigned to CB and Ship Repair activities.
Metalsmiths W	MEW	524	Perform with high skill all welding operations, using both gas and electric equipment. Are assigned to CB and Ship Repair activities.

Naval Job Classifications

Group code Nos.	Group titles	General service	Emergency service			
		ME	MEG	MES	MEB	MEW
42100–42199	Shipfitters and metalsmiths, shipboard	X	X			
42400–42499	Sheetmetal workers and coppersmiths	X		X		
42500–42599	Welders	X	X			X
42600–42699	Blacksmiths and heat treaters	X			X	
42800–42899	Electroplaters	X		X		
42900–42999	Metalworkers miscellaneous	X	X			

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
xxx.100 PRACTICAL FACTORS					
.101 TOOLS					
Use hand tools commonly found in metal work shops	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Dress, sharpen, maintain, and repair hand tools	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Use electric and pneumatic tools commonly found in metal work shop	2, 1, C	2, 1, C	2, 1, C		
Use metal forming and heat treatment equipment	2, 1, C	2, 1, C		3, 2, 1, C	
Make blacksmith's hand tools	1, C			2, 1, C	
.102 BLUEPRINTS					
Read and work from blueprints, plans, and sketches	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Make sketches and drawings for metal repair work	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
103 MATERIALS					
Identify commonly used pipe fitting and plumbing materials	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C		3, 2, 1, C
Identify and distinguish common metals	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Identify and select proper welding electrodes, welding and brazing rods, and fluxes	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C

Qualifications for Advancement in Rating—Continued

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
.104 WELDING, BRAZING, SOLDERING, AND CUTTING					
Perform simple soldering and brazing of copper and brass	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Perform electric arc and oxyacetylene welding	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Make satisfactory tinned surfaces on ferrous and nonferrous metals and satisfactory soldered joints in these materials by sweating, wiping, etc., using both torch and iron	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C		
Make simple straight bevels, cuts, or chamfers in steel plating, using the manual oxyacetylene torch	3, 2, 1, C	3, 2, 1, C		3, 2, 1, C	3, 2, 1, C
Remove defects in ferrous castings, plates, and welded structures, using the manual oxyacetylene torch	2, 1, C	2, 1, C		2, 1, C	2, 1, C
Make satisfactory metal arc welds in steel plates, tubes, and castings of unlimited thickness (all positions)	2, 1, C	2, 1, C			2, 1, C
Make satisfactory metal arc welds in bronze castings (flat positions)	2, 1, C	2, 1, C			2, 1, C

Make satisfactory oxyacetylene or brazed joints in steel and bronze plates and castings (all positions)	1, C	1, C	----------	----------	1, C
Make satisfactory silver-brazed joints in ferrous and nonferrous plating (all positions). Note: See welding test instructions under .400 below	1, C	1, C	----------	----------	1, C
.105 IDENTIFICATION					
Use welder's methods of distinguishing metals by color code, appearance, chip, spark, and gas welding torch tests	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.106 FABRICATION					
Make simple sheet metal structures, such as ventilation duct sections	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	----------	----------
Fabricate the following: funnels, 45° ells, 90° ells, and tees	2, 1, C	2, 1, C	2, 1, C	----------	----------
Straighten welded structures by spot-heating method	1, C	1, C	1, C	1, C	1, C
Make tanks	1, C	1, C	1, C	----------	----------
.107 SHEET METAL WORK					
Make minor sheet metal repairs	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	----------	2, 1, C
Install insulation on sheet metal structures	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	----------	----------
Make patches and repairs to sheet metal parts and sections	2, 1, C	2, 1, C	3, 2, 1, C	----------	----------
Lay out and perform shipboard metal work, including bending, breaking, and rolling	2, 1, C	2, 1, C	2, 1, C	----------	----------

Qualifications for advancement in Rating—Continued

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
.108 PLATE WORK					
Rivet and calk plating sections	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C		
Make general plate repairs aboard ship	2, 1, C	2, 1, C			2, 1, C
Layout and fit plate structures aboard ship and prepare plate for welding	1, C	1, C			1, C
Make lift templates	1, C	1, C			
.109 BLACKSMITH WORK					
Operate and maintain coal, gas, and oil fired forges	3, 2, 1, C	3, 2, 1, C		3, 2, 1, C	
Select size and shape of stock	3, 2, 1, C	3, 2, 1, C		3, 2, 1, C	
Heat-treat metals	2, 1, C	2, 1, C		2, 1, C	
Draw and shape metal into shackles, chain hooks, pipe brackets, and other shapes requiring similar skills	2, 1, C	2, 1, C		2, 1, C	
Forge more complicated metal shapes; heat, draw, and shape metals; judge working condition of hot steel by color; do hot and cold forging	1, C			2, 1, C	
Forge-weld	1, C			3, 2, 1, C	
Case-harden metals	1, C	1, C		2, 1, C	
Make dies and swages	1, C			1, C	

.110 MACHINE FORGING					
Act as leverman on a drop forge, if so assigned	3, 2, 1, C	----------	----------	3, 2, 1, C	----------
Make set-up on a drop forge, if so assigned	1, C	----------	----------	1, C	----------
.111 METAL TESTS					
Conduct standard hardness tests and operate standard testing equipment, provided own ship or station is so equipped	3, 2, 1, C	3, 2, 1, C	----------	3, 2, 1, C	----------
.112 WATERTIGHT INTEGRITY					
Repair watertight doors, ports, and hatches. Conduct compartment and tank air tests for tightness	3, 2, 1, C	3, 2, 1, C	----------	----------	----------
.113 DAMAGE CONTROL					
Assist repair party in maintaining watertight integrity	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Use oxygen breathing apparatus	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.114 ESTIMATES					
Estimate time, material, and labor required for repair of metal structures	1, C	1, C	1, C	1, C	1, C
.115 RECORDS AND REPORTS					
Maintain records, check-off lists, and reports for own unit	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Make job work orders and requisitions	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
.116 SUPPLIES					
Supervise the stowage, preservation, and accounting of stores and spare parts	1, C	1, C	1, C	1, C	1, C
Requisition, account for, stow, and preserve spare parts and replacements	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
.117 SUPERVISION					
Supervise and train personnel engaged in metal work	1, C	1, C	1, C	1, C	1, C
Organize and administer the following:					
Metal work shop	C	C	C		
Blacksmith shop	C			C	
Weld shop	C				C
xxx.200 EXAMINATION SUBJECTS					
.201 NOMENCLATURE					
Tools, materials, and methods common to metal work. Standard metal symbols and abbreviations	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.202 METALS					
Uses of ferrous and nonferrous metals, aboard ship. Uses of various stocks, bars, billets, and shapes	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Characteristics and physical properties of various metals	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
Uses and composition of v[illegible]ous alloys and of fluxes	1, C	1, C	1, C	1, C	1, C

.203 LAYING OUT					
Procedure for laying out and performing metal work. Compute volumes for square and round tanks	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Show by sketch the method of laying out 45° ells, 90° ells, and tees	2, 1, C	2, 1, C	2, 1, C	----------	----------
.204 HEAT TREATMENT					
Heat treating and annealing. Special treatment required for alloys. Stresses in metals resulting from heat and corrective action	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
.205 FORGING					
Principles and practices of forging	2, 1, C	2, 1, C	2, 1, C	3, 2, 1, C	2, 1, C
.206 METAL TESTS					
Tests to identify various metals and alloys	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Standard hardness tests and equipment used	1, C	1, C	1, C	1, C	1, C
.207 FORGE WELDING					
Forge welding, including the preparation of parts, the proper welding heat, and the use of welding compounds. Uses of forge welding	2, 1, C	----------	----------	3, 2, 1, C	----------
.208 WELDING					
Types of materials and their approximate location and usage in the hull structure and fittings of naval vessels	3, 2, 1, C	3, 2, 1, C	----------	----------	3, 2, 1, C
Approved electrodes, welding rods, brazing alloys, and fluxes for welding the various materials used in ship's structure and fittings	3, 2, 1, C	3, 2, 1, C	----------	3, 2, 1, C	3, 2, 1, C

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
.208 WELDING—Continued					
Preheating and postheating treatments required for welding hull structures made of special treatment steels or Class B armor, and attachment of fittings to special alloy steels	2, 1, C	2, 1, C	----------	2, 1, C	3, 2, 1, C
Preferred and alternate processes for welding the materials commonly used in ship structures and fittings	2, 1, C	2, 1, C	----------	----------	2, 1, C
Design details of approved joints in welded ship's structures and fittings and the alternative joint designs which are applicable. Note: See welding test instructions under .400 below	2, 1, C	2, 1, C	----------	----------	2, 1, C
.209 MATHEMATICS					
Ratios, decimals, areas, and volumes applicable to metal work	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.210 CASE HARDENING					
Case hardening, including safety precautions to be observed in using cyanide and proper steps in its application. Uses of case hardening	1, C	1, C	----------	2, 1, C	----------

.211 DAMAGE CONTROL					
Organization of damage control party to which assigned	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Principles of damage control and the duties performed by petty officer in charge of party	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
.212 GASES					
Standard markings for bottled gases and safety precautions required for each	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.213 SPARE PARTS					
Procedure for procuring and accounting for spare parts, tools, and supplies and methods of stowage. Familiarity with allowance lists	2, 1, C	2, 1, C	2, 1, C	2, 1, C	2, 1, C
.214 COMPARTMENTATION					
Compartmentation of own ship	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.215 VENTILATION SYSTEMS					
Indicate by diagram ventilation system of own ship	2, 1, C	2, 1, C	2, 1, C	----------	----------
.216 STANDARDS					
Standards applicable to metal working (*Bureau of Ships Manual*)	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.217 SAFETY PRECAUTIONS					
Safety precautions to be observed while working with metals and machine tools	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Oxygen breathing apparatus; safety precautions	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Safety precautions to be observed in entering closed compartments and voids	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C

Qualifications for Advancement in Rating—Continued

	Applicable rates				
	ME	MEG	MES	MEB	MEW
	520	521	522	523	524
.217 SAFETY PRECAUTIONS—Continued					
Safety precautions to be observed in use and handling of compressed gases employed in welding and cutting operations and in their storage	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Safety precautions to be observed in regard to welding operations, with particular emphasis on fire explosion hazards	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.218 PUBLICATIONS					
Use of handbooks and other technical data	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.219 ORGANIZATION					
Organization of own division	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Organization of Engineering Department of ship to which attached and relationship of other ratings to metal work	1, C	1, C	1, C	1, C	1, C

xxx.300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Metalsmiths advance to Warrant CARPENTER 7741 (*Ship Repair Technician*), broadening their knowledge and training to include functions of the pipe fitter and damage controlman ratings and knowledge of ship salvage and diving operations. Carpenters 7741 act as Assistant Engineering or Repair Officers, Assistant First Lieutenants, Assistant Damage Control Officers, and Assistant Construction Officers (CB).

xxx.400 INSTRUCTIONS FOR TESTING AND QUALIFYING WELDERS

NOTE.—Qualified welders (metal-arc and gas) are divided into three classes: welders, third class; welders, second class; and welders, first class.

.401 QUALIFICATIONS FOR WELDERS, THIRD CLASS

Pass the following qualifications test in accordance with the requirements of the *General Specifications for Inspection of Material—Appendix VII—Welding*, Part E:

Section E–1—Test No. 1 in vertical and overhead position, using approved electrodes.

Section E–2—Test No. 1 in flat position only on steel, bronze, and cast iron, using applicable welding rods.

Section E–5—Tests Nos. 1 and 2.

Pass an examination on these subjects:

Welding symbols, types of welds, nomenclature, and definitions as set forth in sections A–1 and A–2 of the *General Specifications for Inspection of Material—Appendix VII—Welding*, Part A.

Uses of copper, brass, aluminum, iron, steel, and various alloys aboard naval vessels.

Preheat and postheat treatment of metals encountered in welding.

Various types of metal-arc welding sets.

Current and voltage necessary for various sizes and types of electrodes used in metal-arc welding.

Proper flames and technique to be used in gas welding and cutting of various materials, together with proper tip sizes that should be used.

Safety precautions to be observed with regard to welding, cutting, and to handling of gases used.

.402 TESTS AND QUALIFICATIONS FOR WELDERS, SECOND CLASS

Must have served at least 1 year as welders, third class.

Pass the following qualification tests in accordance with the requirements of the *General Specifications for Inspection of Material—Appendix VII—Welding*, Part E:

Section E–1—Test No. 4 using carbon molybdenum pipe and electrodes; Test No. 1 in flat position only, on nickel-copper, corrosion-resisting steel, and aluminum, using applicable electrodes.

.402 TESTS AND QUALIFICATIONS FOR WELDERS, SECOND CLASS—Continued

Section E–2—Test No. 3 using steel tubing and welding rods; Test No. 1 in flat position on aluminum, using applicable welding rod.

Qualify to take charge of welding activities aboard ship and lay out work for men on a job.

.403 TESTS AND QUALIFICATIONS FOR WELDERS, FIRST CLASS

Must have served at least 1 year as welders, second class.

Take charge of a welding shop aboard a tender or repair ship, lay out, and properly supervise the work.

Instruct and qualify candidates for welders, third class and second class.

.404 QUALIFICATION AND REQUALIFICATION

The period of qualification of welders shall be for eighteen (18) months. Qualification or requalification tests will be conducted aboard repair vessels or aboard any vessel having the necessary equipment.

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